JOSEPH J. GRAHAM
GEOLOGY DEPT.
STANFORD UNIVERSIT

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FROM THE
CUSHMAN FOUNDATION
FOR
FORAMINIFERAL RESEARCH

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Contents

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CONTRIBUTIONS FROM THE CUSHMAN FOUNDATION FOR FORAMINIFERAL RESEARCH

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Hans E. Thalmann

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70. FORAMINIFERA FROM THE LOWER TERTIARY OF AMCHITKA ISLAND, ALEUTIAN ISLANDS[1]

RUTH TODD

ABSTRACT—A fauna of 36 species of Foraminifera is recorded and illustrated from two samples of lower Tertiary sediments associated with volcanic rocks on Amchitka Island. Five species are described as new, and 13 others are probably new, but the material is inadequate for description.

A meager and poorly-preserved fauna of Foraminifera was found in two samples from Amchitka Island in the Aleutian chain in Alaska. The material was collected by Howard A. Powers, geologist in charge of the Volcano Investigations Unit of the U. S. Geological Survey.

Sample 22 was obtained from the south coast of Amchitka Island and sample 43 from the north coast of the island. Mr. Powers' description of the sections from which the samples were taken, is as follows:

Sample 22, south coast of Amchitka Island

Coordinates (from Coast and Geodetic Survey manuscript map T-5598, 1950): lat. 51°27′22″ N.; long. 179°03′56″ E.—about 4600 meters southwest of locality of sample 43.

Outcrops in bare marine cliff about 20 feet high, behind sand and pebble beach 30 feet wide.

The formation consists of a series of silt, sandstone, and conglomerate generally of basaltic volcanic rocks. No flows were noted in the section in this vicinity, but some fine layers may be tuffs from an eruption contemporaneous with the erosion that produced the conglomerate. The area is block faulted. The beds locally dip S. 45° E. about 15°.

Section containing fossil horizon:

Top:	Feet
8. Fine conglomerate, cobbles of subrounded basaltic lava up to 2 inches in diameter, matrix of subangular fragments of volcanic rock and fragments of barnacles, pelecypods, and other shells	10+
7. Sandstone, coarse- to medium-grained; constituents similar to bed 8, but shell fragments not conspicuous	2
6. Bedded but not fine laminated dark blue-gray to black silt; compact but not indurated	4
5. Similar to bed 8 but pebbles smaller, not exceeding 1 inch in diameter	6
4. Silt, similar to bed 6.	1
3. "Grit," similar to bed 5.	3
2. Bedded but not fine laminated dark blue-gray to black silt; compact but not indurated. Contains microfossils collected in sample 22.	5
1. "Grit," similar to beds 5 and 3.	5+

Sample 43, north coast of Amchitka Island

Coordinates (from Coast and Geodetic Survey manuscript map T-5597, 1950): lat. 51°28′36″ N., long. 179°08′15″ E.

Outcrops in bare wave-cut bench 20 to 50 feet wide from 1 to 5 feet above high tide.

The formation is made up of a series of sandstones and conglomerates generally of basaltic composition, exposed here in fault blocks giving present attitudes of beds ranging between a dip to S. 45° E. of 30° and a dip to S. 70° E. of 20°. The beds appear to be marine deposits in shallow water not far from land made up of basaltic lavas and tuffs.

Section containing fossil horizon:

Top:	Ft.	In.
5. Conglomerate, indurated; cobbles up to 12 inches, subrounded, of various basaltic lava, matrix lava fragments; some shell fragments	10+	
4. Sandstone, indurated, coarse-grained; subangular fragments of basaltic lavas and tuff ...	1	
3. Silt, black to blue-gray, very compact, not laminated; fine fragments of basaltic tuff. Contains plant fragments, pelecypods, gastropods, and microfossils. At top and bottom sharp, but conformable stratigraphic contacts	0	2
2. Sandstone, coarse-grained; subangular fragments of basaltic lava and tuff	0	8
1. Conglomerate, similar to bed 5.	2+	

The foraminiferal fauna indicates marine deposition at moderate depth, probably not less than 10 fathoms nor more than 40 fathoms. Absence of planktonic species suggests deposition within an embayment or behind a barrier to the circulation of oceanic water.

The combined fauna from both samples consists of only 36 species. Of these, only 18 have been identified or compared with already known species. Eighteen are probably new, but only five of them are represented by material adequate for erection of new species. The other 13 probably new forms are illustrated and briefly described.

The age determination, based on 53 percent of the present fauna (18 named species plus *Bulimina vermiformis* n. sp., which had previously been recorded under another name), is not well established. The fauna is most closely similar to that of Atwill's Tumey formation[2] of California and the Bastendorff shale of Oregon, both assigned to the Oligocene, but there are elements indicating affinities with Eocene formations—the Kreyenhagen shale of California and the Coaledo

1 Publication authorized by the Director, U. S. Geological Survey.

2 The beds for which the name Tumey is used are classed by the U. S. Geological Survey as the upper part of the Kreyenhagen shale.

and Helmick formations of Oregon. The present fauna may, therefore, be assigned with considerable certainty to the lower Tertiary.

TABLE 1 — DISTRIBUTION OF SPECIES
(A = abundant; C = common; R = rare)

	SAMPLE 22	SAMPLE 43
Family Miliolidae		
Pyrgo sp.		R
Family Lagenidae		
Robulus sp. cf. *R. gyroscalprum* (Stache)		R
Dentalina consobrina Orbigny	R	A
soluta Reuss	R	A
communis Orbigny	R	
abbreviata Neugeboren	R	R
? *amchitkaensis* n. sp.		A
sp.		C
? sp.		R
Nodosaria longiscata Orbigny	A	C
? sp.	R	
Family Polymorphinidae		
Globulina sp.	R	
Family Nonionidae		
Nonion planatus Cushman and Thomas	R	
Family Buliminidae		
Bulimina vermiformis n. sp.	R	
Globobulimina pacifica Cushman var. *oregonensis* Cushman and R. E. and K. C. Stewart		R
Uvigerina elongata Cole	R	
Reussella sp.	R	
Siphonodosaria fragilis n. sp.	R	
? sp.	R	
Family Rotaliidae		
Gyroidina girardana (Reuss)		A
condoni (Cushman and Schenck)	R	
condoni (Cushman and Schenck) var. *rotundiformis* Cushman and Simonson		A
sp.	C	
Eponides ? sp. A	R	
? sp. B	R	
Family Cassidulinidae		
Epistominella elegans n. sp.	R	A
Alabamina ? *amchitkaensis* n. sp.		C
Cassidulina globosa Hantken	R	R
crassa Orbigny	C	C
Family Chilostomellidae		
Chilostomella sp.		R
Family Anomalinidae		
Anomalina sp.	R	R
Cibicides pseudoungerianus (Cushman)	A	C
sp. cf. *C. trinitatensis* (Nuttall)	C	R
hodgei Cushman and Schenck	C	
Planulina haydoni Cushman and Schenck	C	
sp.	A	

All specimens, including the types, are deposited in the U. S. National Museum.

SYSTEMATIC DESCRIPTIONS

Family MILIOLIDAE
Genus Pyrgo Defrance, 1824
Pyrgo sp.

Plate 1, figure 1

A single specimen, represented by an internal cast, was found. It is very small and the penultimate chamber is narrowed and reveals the third from the last chamber at either side.

Family LAGENIDAE
Genus **Robulus** Montfort, 1808
Robulus sp. cf. **R. gyroscalprum** (Stache)

Plate 1, figure 2

Cristellaria gyroscalprum Stache, 1864, *Novara*-Exped., Geol. Theil, vol. 1, pt. 2, p. 243, pl. 23, fig. 22.

Two minute forms with angular periphery and slightly curved sutures that are tangential to a large central umbo resemble Stache's species described from the Eocene of New Zealand. Similar forms have also been recorded under this name from the Eocene of California.

Genus **Dentalina** Orbigny, 1826
Dentalina consobrina Orbigny

Plate 1, figures 3, 4

Dentalina consobrina Orbigny, 1846, Foram. Foss. Bass. Tert. Vienne, p. 46, pl. 2, figs. 1-3.

Fragments, none consisting of more than three chambers, occur in both samples. They show a globular proloculus with central, initial spine, and a smooth, polished wall. Similar forms have been recorded from the Oligocene Bastendorff shale of Oregon and from Eocene to Miocene beds in California.

Dentalina soluta Reuss

Plate 1, figures 5-8

Dentalina soluta Reuss, 1851, Zeitschr. Deutsch. Geol. Ges., vol. 3, p. 60, pl. 3, fig. 4.

This species, described from Oligocene material near

Berlin, occurs in the present material only as individual chambers. It is very abundant in sample 43, but rare in sample 22.

The present fragmentary material indicates elongate globular chambers separated by stolon-like connections.

Dentalina communis Orbigny

Plate 1, figures 9, 10

Nodosaria (Dentalina) communis ORBIGNY, 1826, Ann. Sci. Nat., vol. 7, p. 254.

Rare fragments were found in sample 22. They represent the largest form found in this material. The species is very widespread both living and fossil.

Dentalina abbreviata Neugeboren

Plate 1, figure 11

Dentalina abbreviata NEUGEBOREN, 1856, Denkschr. Akad. Wiss. Wien, vol. 12, p. 86, pl. 3, fig. 18.

Rare specimens in both samples appear to belong to this Tertiary European species.

Dentalina ? amchitkaensis n. sp.

Plate 1, figures 12-19

Test elongate, cylindrical, not much tapering, initial end blunt and rounded, apertural end conical, periphery slightly indented toward the apertural end; chambers distinct, early ones about twice as broad as high, later ones nearly twice as high as broad; sutures limbate, obscure in the early part, depressed toward the apertural end; wall calcareous, thick, ornamented with longitudinal costae that are continuous over the sutures, costae ranging from 7 to 13 in number, increasing by intercalation but decreasing in height and strength of development toward the apertural end; aperture indistinct. Maximum length observed (incomplete specimen): 1.12 mm, probable average length of complete specimens (inferred from observed fragments): 2.00 mm, thickness 0.15 mm (initial end) to 0.30 mm (apertural end).

Holotype (U.S.N.M. 548783a) from sample 43, north coast of Amchitka Island, Aleutian Islands, 51°28′36″ N., 179°08′15″ E.

The generic allocation of this species is questionable because the aperture was not observed clearly. It appears to be either radiate or a high cribrate cone.

Except for the aperture and the lack of a compressed initial part, this species is close in appearance to *Amphimorphina ignota* Cushman and Siegfus (Cushman and Siegfus, 1942, p. 410, pl. 16, figs. 31-35), but its costate ornamentation is weaker. It is similar to forms in the Miocene Astoria formation of Oregon referred to *Nodogenerina* sp. (Cushman and R. E. and K. C. Stewart, 1948, p. 17, pl. 2, figs. 9, 10).

This species is the most abundant form in the material studied, but it was found only in sample 43.

Dentalina sp.

Plate 1, figure 20

Only three specimens were found of a form with a hispid surface, few chambers, and a high, conical, radiate aperture.

Dentalina ? sp.

Plate 1, figure 21

A single fragment, here figured, consists of parts of four chambers, cylindrical throughout, with horizontal, limbate, but not depressed sutures. From this fragment, the generic or even family placement is impossible to determine.

Genus **Nodosaria** Lamarck, 1812

Nodosaria longiscata Orbigny

Plate 1, figure 22

Nodosaria longiscata ORBIGNY, 1846, Foram. Foss. Bass. Tert. Vienne, p. 32, pl. 1, figs. 10-12.

This well-known and widely distributed species is fairly common in both samples.

Nodosaria ? sp.

Plate 1, figure 23

The single hispid form, here figured, is probably the initial chamber of a *Nodosaria*, or some similar uniserial genus.

Family POLYMORPHINIDAE

Genus **Globulina** Orbigny, 1839

Globulina sp.

Plate 1, figure 24

Only one specimen belonging to this family was found in sample 22.

Family NONIONIDAE

Genus **Nonion** Montfort, 1808

Nonion planatus Cushman and Thomas

Plate 1, figure 25

Nonion planatum CUSHMAN and THOMAS, 1930, Journ. Pal., vol. 4, p. 37, pl. 3, fig. 5.

One specimen was found of this Eocene species.

Family BULIMINIDAE

Genus **Bulimina** Orbigny, 1826

Bulimina vermiformis n. sp.

Plate 1, figure 30

Bulimina schwageri YOKOYAMA (?) CUSHMAN and DUSENBURY, 1934, Contr. Cushman Lab. Foram. Res., vol. 10, p. 62, pl. 8, fig. 11.

Bulimina cf. *B. schwageri* CUSHMAN and SIMONSON, 1944, Journ. Pal., vol. 18, p. 198, pl. 32, figs. 11, 12.

Test small, elongate, cylindrical, apical end blunt, apertural end obliquely truncate, periphery slightly indented; chambers few, large, slightly inflated, not much increasing in size as added; sutures distinct, in-

cised; wall calcareous, smooth; aperture a large, broad, loop-shaped opening. Length 0.40-0.45 mm, diameter 0.18 mm.

Holotype (U.S.N.M. 548807) from sample 22, south coast of Amchitka Island, Aleutian Islands, 51°27'22" N., 179°03'56" E.

This species differs from *B. elongata* Orbigny (Cushman and Parker, 1947, p. 108, pl. 25, figs. 14-17) in its smaller size, blunt apical end, periphery only slightly indented, and chambers more uniform in size and less inflated. It occurs rarely and was found only in sample 22. Identical specimens have been recorded as *B. schwageri* from the Eocene Poway conglomerate and the Oligocene Tumey formation of California (see synonymy above). *B. schwageri* Yokoyama (Cushman and Parker, 1947, p. 88, pl. 20, figs. 26-28) is considered identical with *B. elongata* Orbigny.

Genus **Globobulimina** Cushman, 1927

Globobulimina pacifica Cushman, var. **oregonensis** Cushman and R. E. and K. C. Stewart

Plate 1, figure 27

Globobulimina pacifica CUSHMAN, var. *oregonensis* CUSHMAN, R. E. and K. C. STEWART, 1948, Bull. No. 36, Oregon Dept. Geol. and Min. Ind., pt. 5, 1947, p. 101, pl. 12, fig. 13.

A single specimen was found in sample 43. The variety was described and is thus far known only from several localities in the upper Eocene Coaledo and Helmick formations of Oregon.

Genus **Uvigerina** Orbigny, 1826

Uvigerina elongata Cole

Plate 1, figure 28

Uvigerina elongata COLE, 1927, Bull. Amer. Pal., vol. 14, No. 51, p. 26, pl. 4, figs. 2, 3.

A single specimen appears to be identical with this species described from the Eocene Guayabal formation of Mexico.

Genus **Reussella** Galloway, 1933

Reussella sp.

Plate 1, figure 29

The specimen figured from sample 22 was the only one found. It appears to be undescribed.

Genus **Siphonodosaria** A. Silvestri, 1924

Siphonodosaria fragilis n. sp.

Plate 1, figure 26

Test small, fragile, elongate, straight; chambers uniserial, distinct, inflated, gradually increasing in size as added; sutures horizontal, depressed, limbate and thick; wall very finely hispid; aperture at the end of a short neck, circular, large, surrounded by a thin and narrow, phialine lip. Length of holotype 0.52 mm, diameter 0.10 mm.

Holotype (U.S.N.M. 548805) from sample 22, south coast of Amchitka Island, Aleutian Islands, 51°27'22" N., 179°03'56" E.

This species differs from *S. cooperensis* (Cushman) (1935, p. 34, pl. 12, fig. 13) in the sutures being less sharply incised but the chambers being more distinctly separated from one another by the thickened sutures.

Siphonodosaria ? sp.

Plate 1, figure 31

Two fragmentary specimens of a smooth-walled uniserial form with short, inflated chambers and thickened horizontal sutures are questionably referred to this genus.

Family ROTALIIDAE

Genus **Gyroidina** Orbigny, 1826

Gyroidina girardana (Reuss)

Plate 1, figure 32

Gyroidina girardana CUSHMAN, 1927, Journ. Pal., vol. 1, p. 164, pl. 25, figs. 7-9.

Abundant specimens in sample 43 have seven distinct chambers in the last whorl. A bluntly angled periphery that may be slightly upturned around the edge, together with a depressed spiral suture gives the typical dorsal appearance of this species. The umbilicus is small and the apertural face of the last chamber is high and concave.

Gyroidina condoni (Cushman and Schenck)

Plate 2, figure 1

Eponides condoni CUSHMAN and SCHENCK, 1928, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 17, p. 313, pl. 44, figs. 6, 7.

A single specimen of this species described from the Keasy shale of Oregon was found.

Gyroidina condoni (Cushman and Schenck), var. **rotundiformis** Cushman and Simonson

Plate 2, figure 2

Gyroidina condoni rotundiformis CUSHMAN and SIMONSON, 1944, Journ. Pal., vol. 18, p. 201, pl. 33, figs. 17-19.

Abundant specimens appear to be identical with types of this species from the Oligocene Tumey formation of California.

Gyroidina sp.

Plate 2, figure 3

Test small, thick, periphery rounded, dorsal side flat, ventral side convex; seven chambers in the last whorl; sutures distinct, straight and slightly oblique on the dorsal side, slightly curved on the ventral side; umbilicus small.

Genus **Eponides** Montfort, 1808
Eponides ? sp. A
Plate 2, figure 4

The single figured specimen was the only one found. In its coarsely perforate wall and numerous chambers and whorls, it resembles specimens from the lower Oligocene of Cuba (Palmer and Bermudez, 1936, p. 303, pl. 20, figs. 7-9) and from the upper Oligocene of the Dominican Republic (Bermudez, 1949, p. 250, pl. 17, figs. 28-30) that have been referred to *Eponides umbonatus* (Reuss) var. *multiseptus* (Koch).

The generic allocation is questionable, as the last chamber is broken away and thus the aperture cannot be observed. The coarsely perforate wall suggests the genus *Cibicides*.

Eponides ? sp. B
Plate 2, figure 5

Test small, globular, composed of three whorls; chambers few, five in the last whorl; sutures distinct but not depressed, gently curved and oblique; aperture not observed. Diameter 0.25 mm, thickness 0.25 mm.

This species is represented by only two specimens, both of which are incomplete on the ventral side.

Family CASSIDULINIDAE
Genus **Epistominella** Husezima and Maruhasi, 1944
Epistominella elegans n. sp.
Plate 2, figure 6

Test biconvex, ventral side more convex than the dorsal; periphery acute, surrounded by a narrow, blunt keel; chambers distinct, five or six in the last whorl; sutures distinct, not depressed, straight and tangential on the dorsal side, radial but curved at their inner ends on the ventral side; wall smooth, finely perforate; aperture a low elongate opening under the ventral edge of the last-formed chamber beginning near the umbilicus and extending almost to the periphery and thence in an elongate extension into the apertural face parallel with the plane of the test. Diameter 0.40-0.50 mm (rarely as large as 0.65 mm), thickness 0.20-0.25 mm.

Holotype (U.S.N.M. 548824) from sample 43, north coast of Amchitka Island, Aleutian Islands, 51°28′36″ N., 179°08′15″ E.

This species differs from *E. atlantisae* (Cushman) var. *dissonata* (Cushman and Renz) (1948, p. 35, pl. 7, figs. 11, 12) from the Eocene Navet formation of Trinidad in the more sharply curved inner ends of the ventral sutures, the lack of a ventral umbo of clear shell material, and a less widely open peripheral extension of the aperture.

Epistominella elegans n. sp. occurs abundantly in sample 43 and rarely in sample 22.

Genus **Alabamina** Toulmin, 1941
Alabamina ? amchitkaensis n. sp.
Plate 2, figure 7

Test biconvex, dorsal side very slightly convex, ventral side strongly convex but with a tendency to develop a peripheral flange around the later chambers; periphery acute, not keeled; chambers indistinct, about five in the last whorl; sutures indistinct, not depressed, oblique on the dorsal side, radial and gently curved on the ventral side; wall smooth, distinctly perforate; a prominent apertural fold extending from the peripheral edge well into the apertural face, true aperture not observed. Diameter 0.40-0.55 mm, thickness 0.20-0.30 mm.

Holotype (U.S.N.M. 548827) from sample 43, north coast of Amchitka Island, Aleutian Islands, 51°28′36″ N., 179°08′15″ E.

This species differs from *A. wilcoxensis* Toulmin (1941, p. 603, pl. 81, figs. 10-14) from the Eocene of Alabama in the more acute periphery, less distinct sutures, and more highly convex ventral side.

Genus **Cassidulina** Orbigny, 1826
Cassidulina globosa Hantken
Plate 2, figure 8

Cassidulina globosa Hantken, 1881, Mitth. Jahrb. K. Ungar. Geol. Anstalt, vol. 4, 1875, p. 64, pl. 16, fig. 2.

Single specimens from both samples are like this species, which was described from the Eocene of Hungary and has been recorded mostly from Eocene beds.

Cassidulina crassa Orbigny
Plate 2, figure 9

Cassidulina crassa Orbigny, 1839, Voy. Amér. Mérid., vol. 5, pt. 5, "Foraminifères," p. 56, pl. 7, figs. 18-20.

This species was found commonly in both samples. Specimens are small (the largest 0.40 mm in diameter), composed of four pairs of chambers per whorl, with smoothly rounded periphery.

Family CHILOSTOMELLIDAE
Genus **Chilostomella** Reuss, 1850
Chilostomella sp.
Plate 2, figure 10

The single incomplete specimen was the only one found. It does not appear to belong to any described species.

Family ANOMALINIDAE
Genus **Anomalina** Orbigny, 1826
Anomalina sp.
Plate 2, figure 11

Two specimens of a small, compressed form with nine visible chambers and distinct and limbate sutures were found, one in each sample.

Genus **Cibicides** Montfort, 1808
Cibicides pseudoungerianus (Cushman)
Plate 2, figures 12, 13

Truncatulina pseudoungeriana CUSHMAN, 1922, U. S. Geol. Survey Prof. Paper 129-E, p. 97, pl. 20, fig. 9.

This species described from the Oligocene Byram marl of Mississippi occurs rarely in sample 43 and commonly in sample 22. The specimens are characterized by the coarse perforations of the wall, especially on the dorsal side. Most of the specimens are planoconvex. The species is widely known from Eocene to Recent.

Cibicides sp. cf. **C. trinitatensis** (Nuttall)
Plate 2, figure 15

Truncatulina trinitatensis NUTTALL, 1928, Quart. Journ. Geol. Soc., vol. 84, p. 97, pl. 7, figs. 3, 5.

A few small specimens with coarsely perforate wall, a smooth ventral umbo, and sutures incised around an irregular central umbo on the dorsal side may be compared to this species described from the Tertiary of Trinidad.

Cibicides hodgei Cushman and Schenck
Plate 2, figure 14

Cibicides hodgei CUSHMAN and SCHENCK, 1928, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 17, p. 315, pl. 45, figs. 3-5.

A few specimens, although much smaller than the types, are referable to this species described from the Bastendorff shale of Oregon. The test is plano-convex. The wall is finely but distinctly perforate, and the sutures are glassy and limbate.

Genus **Planulina** Orbigny, 1826
Planulina haydoni Cushman and Schenck
Plate 2, figure 16

Planulina haydoni CUSHMAN and SCHENCK, 1928, Univ. Calif. Publ., Bull. Dept. Geol. Sci., vol. 17, p. 316, pl. 45, fig. 7.

This species described from the Oligocene Bastendorff shale of Oregon and known from the Oligocene Tumey formation of California and the lower Tertiary of Coos Bay, Oregon, occurs in sample 22.

Planulina sp.
Plate 2, figure 17

Abundant specimens of a much compressed, small form seem to be undescribed, but are inadequate for the erection of a new species. They are all deformed, collapsed, or broken as a result of fossilization and it is impossible to determine accurately the number of chambers or how much of the compression is of secondary origin. The test appears to have been smooth without either conspicuous perforations or limbate sutures.

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EXPLANATION OF PLATE 1

FIGS.		PAGE
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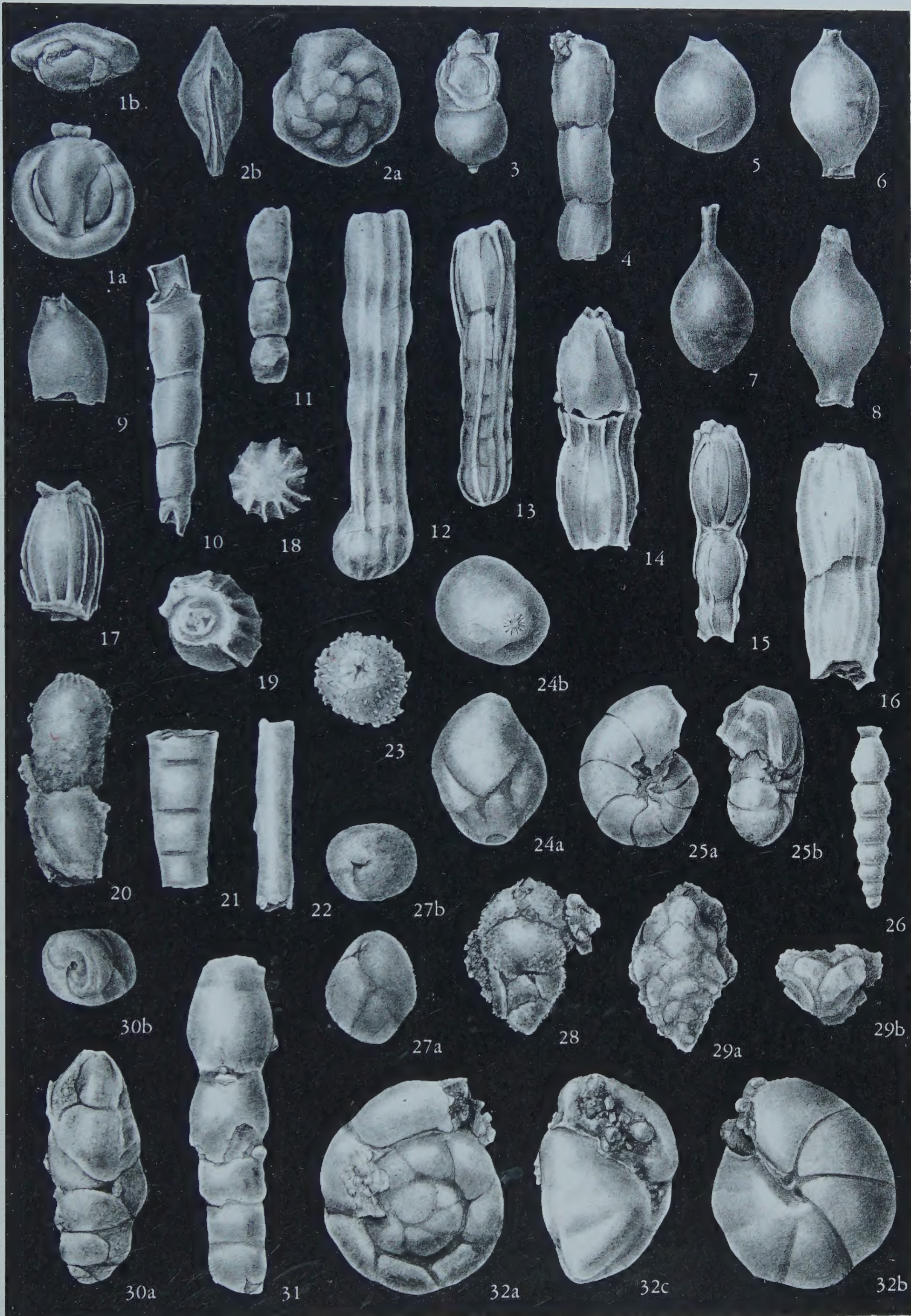
3, 4.	*Dentalina consobrina* Orbigny. 3, Initial end. Sample 43. × 44.	2
5-8.	*Dentalina soluta* Reuss. 5, Initial end. 6-8, Single chambers showing variation in shape. Sample 43. × 44.	2
9, 10.	*Dentalina communis* Orbigny. 9, Apertural end. Sample 22. × 27.	3
11.	*Dentalina abbreviata* Neugeboren. Sample 43. × 56.	3
12-19.	*Dentalina ? amchitkaensis* n. sp. 13, Holotype. 12, 14-19, Paratypes. 12, 13, showing initial ends. 14, showing apertural end. 18, 19, end views. Sample 43. × 56.	3
20.	*Dentalina* sp. Apertural end with radiate aperture. Sample 43. × 44.	3
21.	*Dentalina* ? sp. Sample 43. × 44.	3
22.	*Nodosaria longiscata* Orbigny. Sample 43. × 56.	3
23.	*Nodosaria* ? sp. Top view of broken-off initial end. Sample 22. × 56.	3
24.	*Globulina* sp. 24a, Side view; 24b, top view. Sample 22. × 56.	3
25.	*Nonion planatus* Cushman and Thomas. 25a, Side view; 25b, peripheral view. Sample 22. × 85.	3
26.	*Siphonodosaria fragilis* n. sp. Holotype. Sample 22. × 56.	3
27.	*Globobulimina pacifica* Cushman var. *oregonensis* Cushman and R. E. and K. C. Stewart. 27a, Side view; 27b, top view. Sample 43. × 27.	4
28.	*Uvigerina elongata* Cole. Sample 22. × 56.	4
29.	*Reussella* sp. 29a, Side view; 29b, top view. Sample 22. × 85.	4
30.	*Bulimina vermiformis* n. sp. Holotype. 30a, Side view; 30b, top view. Sample 22. × 85.	3
31.	*Siphonodosaria* ? sp. Sample 22. × 56.	4
32.	*Gyroidina girardana* (Reuss). 32a, Dorsal view; 32b, ventral view; 32c, peripheral view. Sample 43. × 56.	4

Illustrations drawn by Carolyn Bartlett



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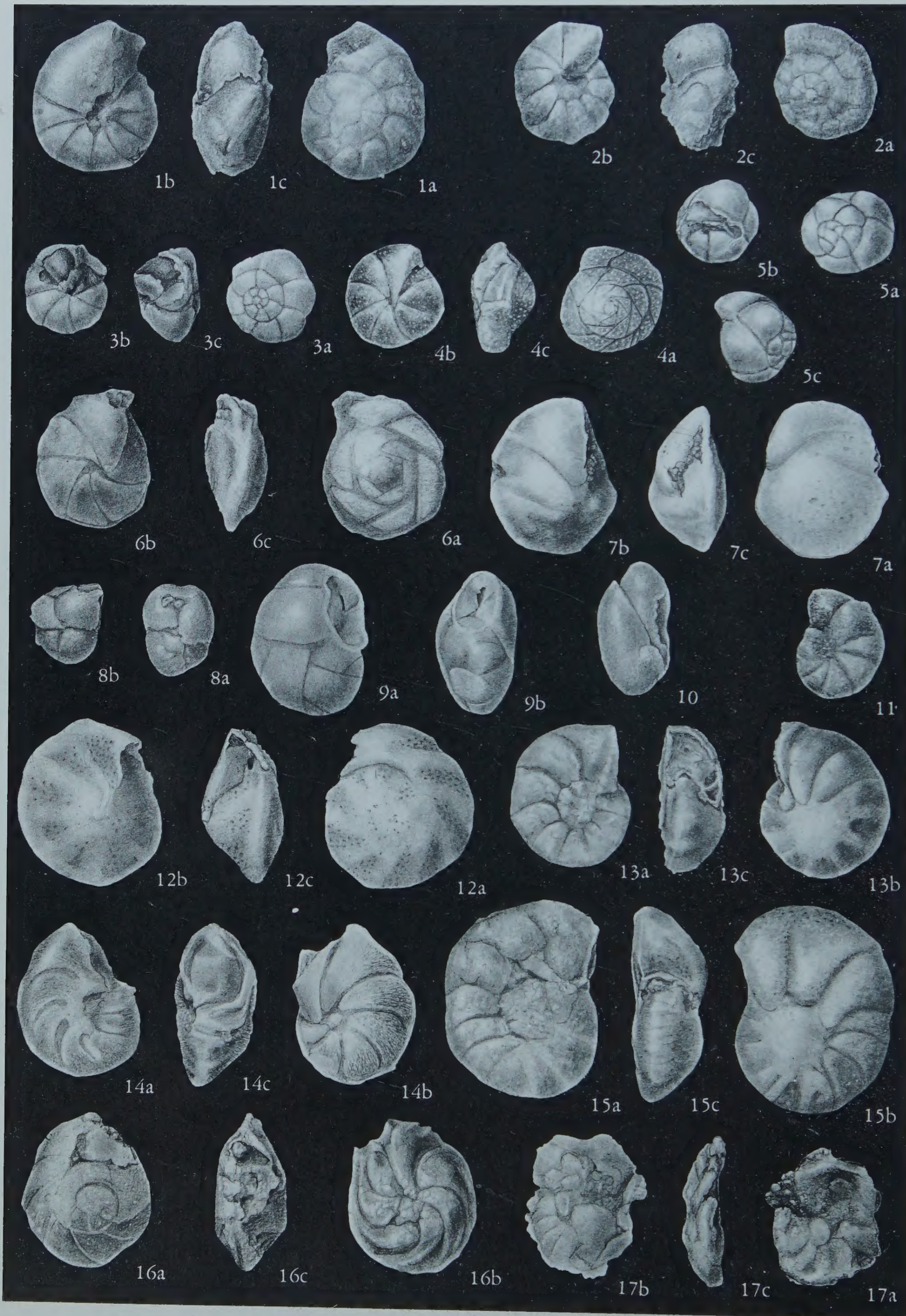
Todd: Tertiary Foraminifera from Amchitka Island



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Todd: Tertiary Foraminifera from Amchitka Island

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71. FORAMINIFERA OF GREAT POND EAST FALMOUTH, MASSACHUSETTS[1]

RUSHDI SAID
Gizeh, Egypt

ABSTRACT—Results are given of a quantitative study of the Foraminifera of Great Pond, East Falmouth, Massachusetts. Three foraminiferal populations are noted: a **Trochammina** assemblage in areas temporarily exposed by tidal action, an **Elphidium** population in regions where salinity fluctuated greatly but has never been recorded below 20 o/oo, and an **Ammobaculites** assemblage in areas with salinities lower than 20 o/oo. The small foraminiferal numbers are probably due to the amount of food and to oxygen content.

1 Contribution No. 588 from the Woods Hole Oceanographic Institution.

EXPLANATION OF PLATE 2

(Except as otherwise indicated for figs. 8, 9, a, Dorsal view; b, ventral view; c, peripheral view.)
(Figures 6, 7, × 44; all others, × 56)

FIGS.		PAGE
1.	*Gyroidina condoni* (Cushman and Schenck). Sample 22.	4
2.	*Gyroidina condoni* (Cushman and Schenck) var. *rotundiformis* Cushman and Simonson. Sample 43.	4
3.	*Gyroidina* sp. Sample 22.	4
4.	*Eponides* ? sp. A. Sample 22.	5
5.	*Eponides* ? sp. B. Sample 22.	5
6.	*Epistominella elegans* n. sp. Holotype. Sample 43.	5
7.	*Alabamina* ? *amchitkaensis* n. sp. Holotype. Sample 43.	5
8.	*Cassidulina globosa* Hantken. 8a, Apertural view; 8b, side view. Sample 43.	5
9.	*Cassidulina crassa* Orbigny. 9a, Side view; 9b, peripheral view. Sample 43.	5
10.	*Chilostomella* sp. Sample 43.	5
11.	*Anomalina* sp. Sample 22.	5
12, 13.	*Cibicides pseudoungerianus* (Cushman). 12, Sample 43. 13, Sample 22.	6
14.	*Cibicides hodgei* Cushman and Schenck. Sample 22.	6
15.	*Cibicides* sp. cf. *C. trinitatensis* (Nuttall). Sample 43.	6
16.	*Planulina haydoni* Cushman and Schenck. Sample 22.	6
17.	*Planulina* sp. Sample 22.	6

Illustrations drawn by Carolyn Bartlett

INTRODUCTION

Great Pond, a narrow embayment on the south shore of Cape Cod, is about a mile and a half in length, less than a quarter of a mile in width, and has a maximum depth of nine feet in high tide. The northern part of the Pond is divided into two narrow arms, the eastern one of which receives the outflow of Coonamessett River. The Pond is connected by a short, narrow channel with Vineyard Sound to the south.

The distribution of salinity is subject to seasonal and tidal changes, but in general the salinity gradually decreases towards the north and away from Vineyard Sound. In the main body of the Pond, salinity gradients decrease steadily but gradually towards the north. In the eastern arm salinity gradients are rapid and steep. The greatest change in bottom salinity per unit distance is at the southern tip of the eastern arm where, at least during part of the high tide, a 10 o/oo change in salinity occurs in a distance of less than 600 feet. Figure 3 shows the salinity gradients.

Seasonal temperature changes are marked and the bottom is subjected to large annual fluctuations, from nearly freezing in winter to about 77°F in August. The greatest change in temperature per unit distance also occurs in the southern part of the eastern arm (Fig. 3).

The Pond receives a large amount of fresh water. The exchange of its water with that of Vineyard Sound has been discussed by Ketchum (1951). The bottom is covered with uncompacted black, sticky mud whose composition approximates the muds described by Bourcart and Francis-Boeuf (1942) from French estuaries. The texture is due to organic matter in various stages of decomposition. The loss of weight by ignition of the sediment is 22%. The nature of the mud results in an environment in which the decomposition of organic matter releases both hydrogen sulfide and methane gas. The southernmost part of the Pond is sandy and is submerged for a brief period during high tides.

Throughout the year the organic production in the Pond is much higher than that in Vineyard Sound. It reaches a maximum in summer. The percentage of phytoplankton and zooplankton increases from the Sound towards the eastern arm. The phytoplankton species in the arm are different from those in the Pond whereas the zooplankton species in both the Pond and the arm are the same.

Acknowledgments.—The author is indebted to Alfred C. Redfield and Henry C. Stetson for suggesting the problem and to Edward M. Hulburt, John P. Barlow, and Harry J. Turner for use of their unpublished data on the salinity, temperature and plankton populations of the Pond. He wishes also to thank John P. Barlow for assistance in the field.

Collection of samples.—Thirty-one samples (eighteen cores and thirteen grabs) were collected from Great Pond during the summer of 1951. The core samples were obtained by means of a removable plastic liner, 30 cm. in length, affixed to the end of a long wooden rod. Thus short cores could be acquired with a minimum amount of effort in a simple skiff equipped with only an outboard motor. Grab samples were obtained either by hand in shallow waters or by a simple snapper device in deeper waters. Only the topmost six inches of the cores were examined. Figure 1 shows the areal distribution of samples and the type of bottom of the Pond.

SYSTEMATIC WORK

Fourteen species of Foraminifera were obtained in Great Pond:

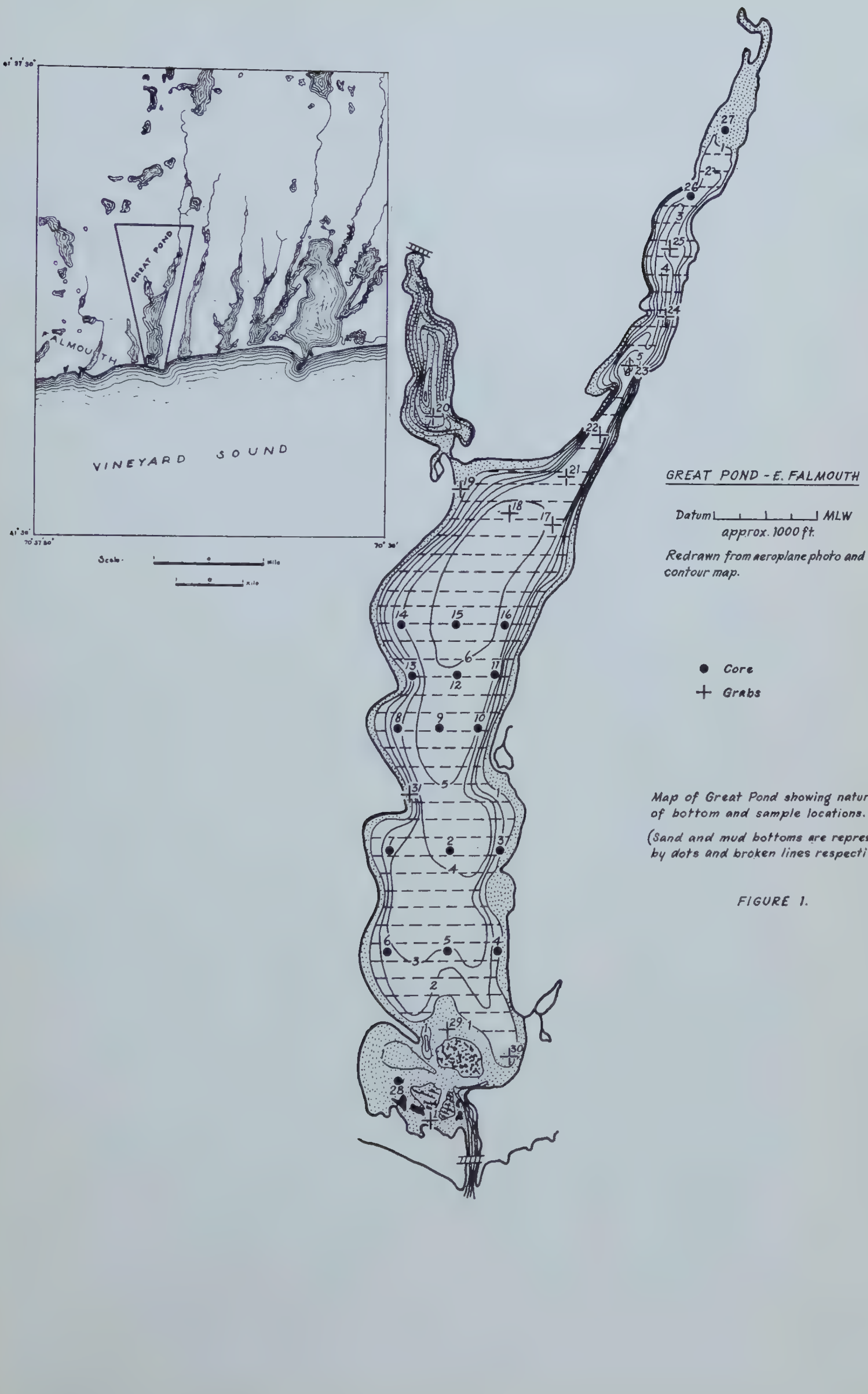
Ammobaculites cassis (Parker)
Ammobaculites sp.
Elphidium incertum (Williamson)
E. frigidum (Cushman)
E. subarcticum (Cushman)
Buccella calida (Cushman and Cole)
Labrospira crassimargo (Norman)
Miliammina fusca (H. B. Brady)
Nonion tisburyensis (Butcher)
Reophax sp. cf. *R. arctica* (H. B. Brady)
Rotalia beccarii (Linne)
Trochammina inflata (Montagu)
T. lobata (Cushman)
T. macresens (H. B. Brady)

Except for the common New England species *Elphidium incertum, Buccella calida, Trochammina inflata, T. lobata, and Rotalia beccarii,* typical subarctic forms predominate. Cape Cod appears to be the southernmost occurrence from which they have been recorded. All species are either wholly restricted to or exceptionally well developed in brackish estuarine areas. Most species have been described and figured by Phleger and Walton (1950). Also, *Ammobaculites* sp. is the same as that described and figured by these authors (p. 277, pl. 1, fig. 15).

The Woods Hole region lies within a district in which the distribution of Foraminifera of various habitats has been critically studied (Parker, 1948 and 1952; Phleger and Walton, 1950; Said, 1951; and Phleger, 1952). Three major biotopes are represented: the continental shelf, the bay, and the estuary. The total number of Foraminifera and the number of species decreases from the shelf to the estuary. There are several species characteristic of each biotope; however, many species are present in all three biotopes (Parker, 1952, list).

THE DISTRIBUTION OF FORAMINIFERA

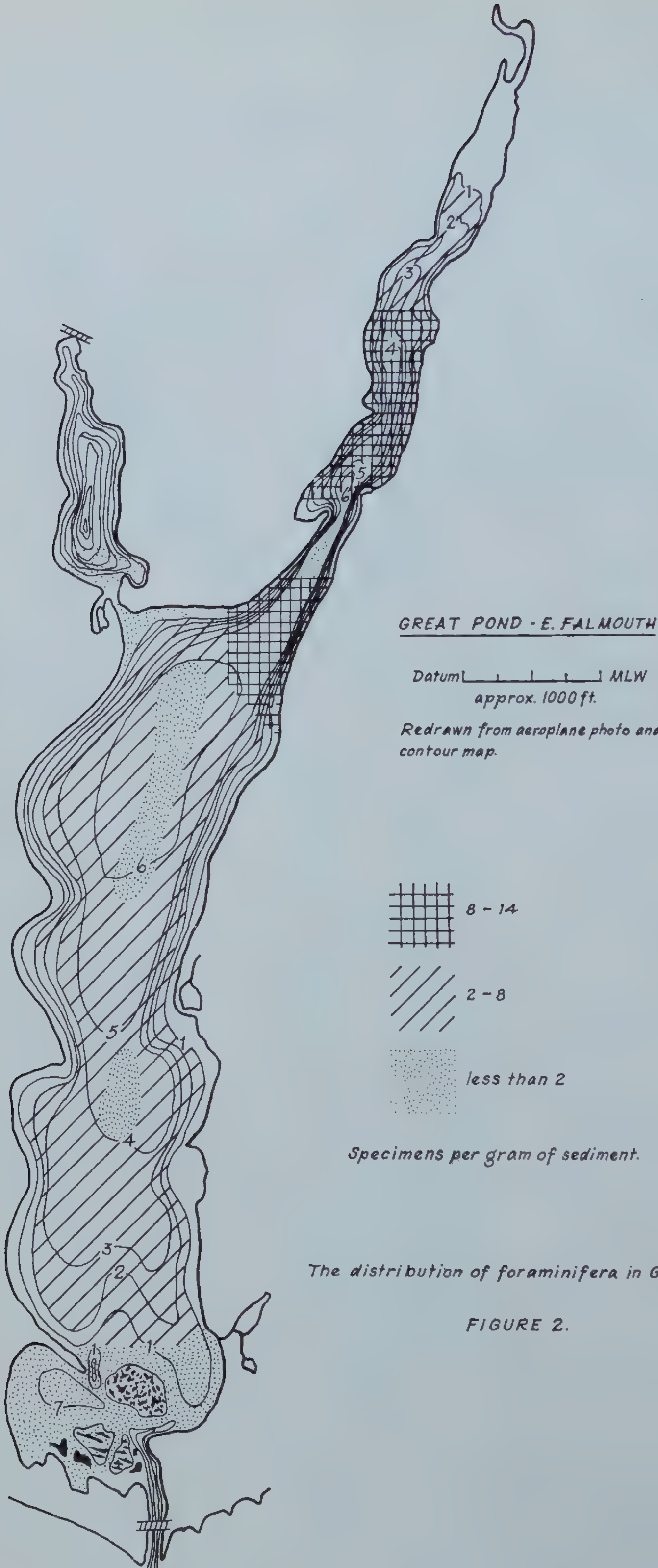
Method of Study.—Sixty grams of dried core samples and forty grams of dried grab samples were wet-sieved. Material finer than 0.07 mm. (200 mesh) was



Map of Great Pond showing nature of bottom and sample locations.

(Sand and mud bottoms are represented by dots and broken lines respectively.)

FIGURE 1.



The distribution of foraminifera in Great Pond.

FIGURE 2.

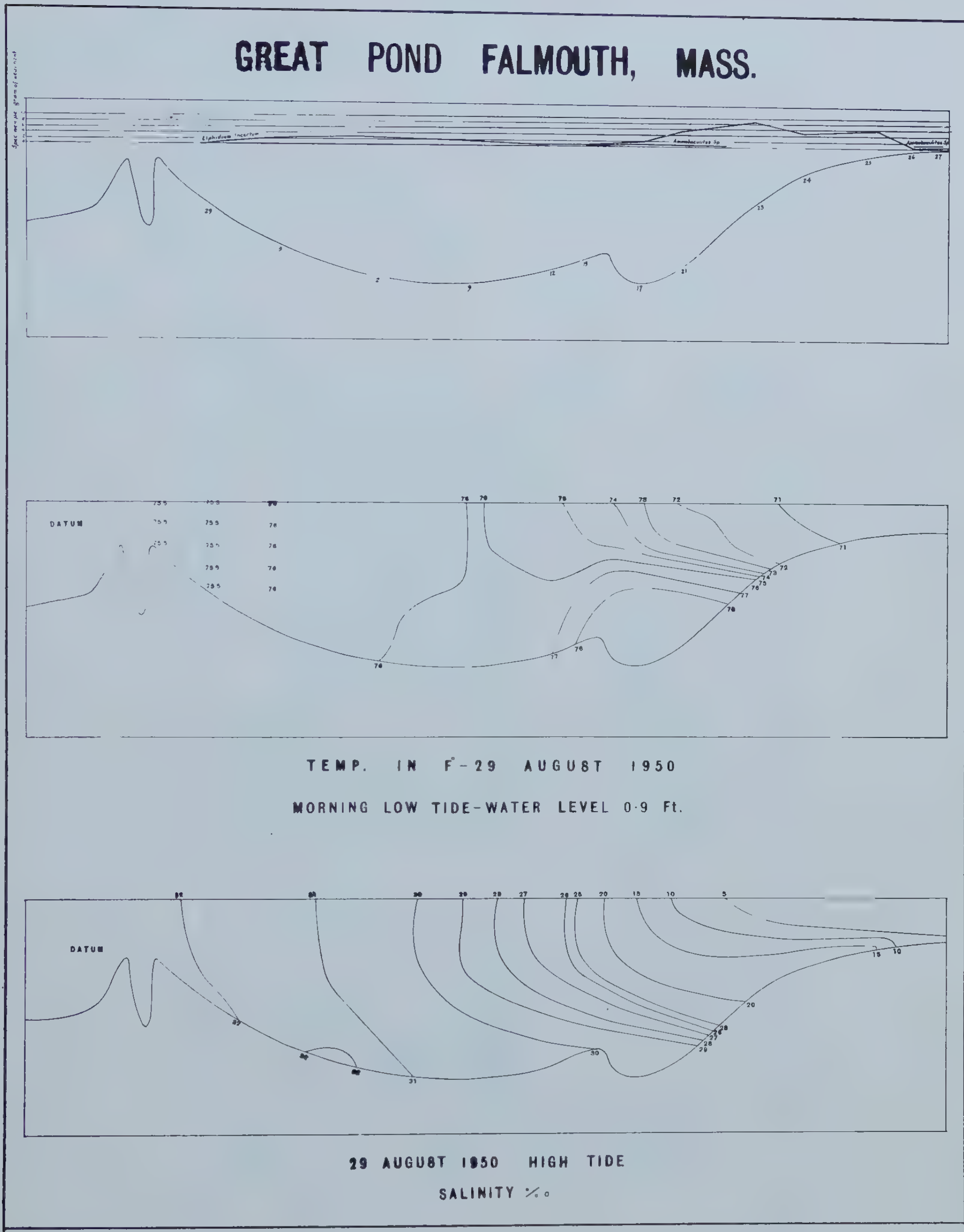


Figure 3: Longitudinal profiles of Great Pond showing from top to bottom: frequency fluctuations of some of the common species of Foraminifera; temperature isotherms and salinity gradients.

TABLE I

	Trochammina inflata	Labrospira crassomargo	Ammobaculites sp.	Miliammina fusca	Elphidium incertum	E. frigidum	Buccella calida	Nonion tisburyensis	Reophax arctica	Foraminiferal numbers
1	Less than 1								Less than 1	1
2					Less than 1	Less than 1	Less than 1	Less than 1		1
3					1-4	Less than 1	Less than 1	Less than 1		4
4					1-4	Less than 1	Less than 1	Less than 1		4
5					1-4	Less than 1	Less than 1	Less than 1		4
6					1-4	Less than 1	Less than 1	Less than 1		4
7					1-4	Less than 1	Less than 1	Less than 1		6
8			Less than 1		1-4	Less than 1	Less than 1	Less than 1		2
9			Less than 1		1-4	Less than 1	Less than 1	Less than 1		3
10			Less than 1		1-4	Less than 1	Less than 1	Less than 1		2
11			Less than 1		1-4	Less than 1	Less than 1	Less than 1		2
12			Less than 1		Less than 1	Less than 1	Less than 1	Less than 1	Less than 1	X
13		Less than 1	Less than 1		1-4	Less than 1	Less than 1	Less than 1	Less than 1	2
14		Less than 1	Less than 1		1-4	Less than 1	Less than 1	Less than 1	Less than 1	2
15		Less than 1	Less than 1		1-4	Less than 1	Less than 1	Less than 1	Less than 1	2
16		Less than 1	Less than 1		1-4	Less than 1	Less than 1	Less than 1	Less than 1	2
17		Less than 1	1-4		1-4	Less than 1	Less than 1	1-4	Less than 1	8
18										0
19		Less than 1	1-4		Less than 1	Less than 1	Less than 1	1-4		6
20										0
21		Less than 1	1-4		More than 4	Less than 1	Less than 1	Less than 1		8
22		Less than 1	Less than 1		Less than 1	Less than 1	Less than 1	Less than 1		1
23					More than 4	1-4	1-4	Less than 1		14
24					More than 4	1-4	1-4	Less than 1		8
25					More than 4	1-4	1-4	Less than 1		9
26		Less than 1	Less than 1	Less than 1	Less than 1			Less than 1		2
27		Less than 1	Less than 1	Less than 1	Less than 1	Less than 1			Less than 1	2
28		Less than 1	Less than 1	Less than 1	Less than 1	Less than 1			Less than 1	X
29					Less than 1		Less than 1	Less than 1		X
30	Less than 1									X
31	Less than 1				Less than 1					X

None — Less than 1 — 1-4 — More than 4

Specimens in one gram of sediment

discarded. The coarser fractions were then treated by carbon tetrachloride for separation of the Foraminifera. The Foraminifera in each sample were then counted, using the method previously described by the author (1950). Table 1 presents the results of this quantitative work in terms of numbers of specimens per gram of sediment. Only nine of the fourteen species recorded in the area were sufficiently abundant to be counted separately. These species only appear in Table 1. The remainder of the species occur in small numbers and nowhere exceed 5% of the total number of Foraminifera.

Total numbers of Foraminifera.—The total foraminiferal numbers in all samples were low, the average foraminiferal number of all samples being 3 specimens per gram. This is much lower than the 200 to 300 per gram content in the continental shelf of the Eastern Atlantic Ocean (Parker, 1948), or the 40 to 50 per gram in Narragansett Bay (Said, 1951). This small number of Foraminifera in the Pond may be due to an environment unfavorable for a flourishing benthonic foraminiferal assemblage, in spite of the fact that organic production is high. In the Great Pond type of basin where the bottom is almost unaerated it appears that oxygen plays an important role in limiting the number of benthonic forms. The nature of the bottom of the Pond is apparently of importance in governing the growth of benthonic foraminiferal populations. In aerated basins where the turnover, exchange of water, and type of bottom sediment permit an abundance of oxygen at the bottom, the oxygen seems to play an insignificant role in the appearance of Foraminifera. This has been pointed out by the author in his study on the distribution of Foraminifera in the Red Sea (1950). In basins where the bottom is unaerated, oxygen appears to be an important limiting factor.

Figure 2 shows the distribution of Foraminifera in Great Pond, and Figure 3 represents the frequency fluctuations of some of the more common species of Foraminifera appearing in the Pond from the Vineyard Sound northward to the eastern arm. The abundance and distribution of Foraminifera coincide with those of the zooplankton population. The largest foraminiferal numbers occur in the southern portion of the eastern arm (Samples no. 23 - 25), an area characterized also by the highest numbers of zooplankton. That this area of maximum development of benthonic Foraminifera shows the greatest fluctuations of both temperature and salinity is interesting. In spite of the fact that this part of the arm is restricted in areal extent, the salinity varies from 30 to 40 o/oo within a distance of not more than 600 feet. One small area may be subjected to such radical changes as 15 to 30 o/oo in one tidal cycle. In spite of these great salinity and temperature variations the samples show remarkable uniformity both in the foraminiferal species and in the total foraminiferal numbers, suggesting that these species are extremely stenohaline and stenothermal.

Size of Foraminifera.—The foraminifers in the Pond are of smaller size than the average in the Vineyard Sound, probably as the result of the unaerated bottom. For example, *Elphidium incertum* is about one-half the size of those in the Sound, a dwarfing apparently due to the smaller amount of oxygen present.

Number of species.—The number of species in the Pond is limited by several unfavorable conditions; namely, the unaerated bottom, the vigorous fluctuations of salinity and temperature, and periods of dryness for at least part of the day.

The foraminiferal numbers increase northward from the Sound to the arm in the same manner as previously noted in Narragansett Bay (Said, 1951). A similar observation has been made of the zooplankton populations (John P. Barlow, oral communication).

Distribution of species.—There are three distinct populations in the Pond: an *Elphidium* assemblage abundant in the main body of the Pond and the southern reaches of the arm; an *Ammobaculites* assemblage with other arenaceous Foraminifera in the northern reaches of the arm; and a *Trochammina* assemblage common in the sub-tidal shallow flat in the southern reaches of the Pond.

The *Elphidium* assemblage is comprised of calcareous forms which form either the entire assemblage or at least a large percentage of it. In the latter case there is an influx of some arenaceous species in a few localities with a general trend in increase of these arenaceous forms to the north of the main body of the Pond. In the southern reaches of the arm the assemblage is composed entirely of calcareous forms of great uniformity.

The *Ammobaculites* assemblage (with other arenaceous species) occurs in the northern reaches of the arm. Few calcareous forms are present. The change from a calcareous assemblage (*Elphidium*) to an arenaceous assemblage is sudden and apparently related to salinity inasmuch as the *Elphidium* assemblage, while tolerating great salinity fluctuations, does not seem to withstand waters less saline than 20 o/oo. This low salinity is present at least part of the time in the northern arenaceous Foraminifera zone, but has not been recorded at any time in the main body of the Pond.

The *Trochammina* assemblage occurs in a sandy and very shallow area subjected to less fluctuations in salinity than any other part of the Pond. It is also wetted daily by the tides. This zone is probably similar to the *Spartina glabra* zone of Johnson (1925, pp. 522-528).

SUMMARY AND CONCLUSIONS

Great Pond is a shallow embayment which represents one of the better known estuaries of the eastern

coast of North America. The study of the distribution of Foraminifera in the Pond should therefore give definite results as to the response of the contained species to the physical conditions of the environment.

All species recorded are of the subarctic type, and it seems probable that the low temperature to which the Pond is subjected during the winter months thus determines the kind of species that can persist. Temperature cannot, however, account for the distribution pattern within the area. A similar observation has been made by Phleger and Walton (1950) and Said (1951).

The foraminiferal numbers in the Pond are the lowest ever recorded in recent marine sediments. The small numbers are believed to be the result of an almost unaerated bottom. The most important single factor determining the appearance and abundance of benthonic Foraminifera seems to be the hydrographic conditions of the basin. Although oxygen appears to be of no consequence in the distribution of Foraminifera in aerated basins (Said, 1951), it becomes an important factor in unaerated basins. The influence of oxygen is limited not only to lowering the foraminiferal numbers but also has an effect in the dwarfing of the foraminiferal fauna. Lalicker (1948) summarized the knowledge of the dwarfing of protozoan faunas and has cited examples from the geologic record. The amount of oxygen and the hydrographic condition of the basin of deposition seem to be much more important than any factor hitherto considered. Dwarfing is probably due to retardation of growth because of a lower metabolic rate under unfavorable condition.

Salinity seems to play an important role in the distribution of Foraminifera. Salinity fluctuations and the oxygen content may account for the small number of species in the Pond, inasmuch as there are only fourteen species in contrast to over 200 species in nearby Vineyard Sound. There are three biofacies in the Pond: a *Trochammina* assemblage, which flourishes in areas with the least salinity fluctuation; an *Elphidium* assemblage which thrives in that part of the Pond where there is vigorous salinity change but the salinity is always greater than 20 o/oo; and an *Ammobaculites* assemblage. *Ammobaculites* also appears in areas with higher salinities but in smaller numbers. It is possible that its numbers increase when the salinity becomes lower than 20 o/oo due to the elimination of other competing species.

Explanation of the distribution of species due to salinity is probably an oversimplification for the nature of the bottom is also an important factor. *Trochammina* appears only in sandy bottoms. *Elphidium incertum clavatum,* common in the New England coast and a species which is always present in association with *E. incertum,* was not observed in the Great Pond apparently due to the fact that the bottom of the Pond is muddy. The species has been observed only on sandy bottoms (Said, 1951). The effect of tidal submergence which subdivided similar embayments into floral zones (Johnson, 1925) is probably important in determining the kind of species that could live in areas which are only briefly wetted. *Trochammina* appears to be able to endure wetting by tidal action for a brief period.

Although salinity appears to be the controlling factor in the distribution of species, the drastic salinity variations common in the southern part of the eastern arm do not seem to affect the character of the fauna in that area. On the contrary, this region is characterized by the most uniform and most abundant foraminiferal fauna in the Pond.

The total foraminiferal numbers increase northward as do the numbers of zooplankton population in the Pond. The low oxygen content reduces numbers, leaving the Great Pond with much lower numbers than Vineyard Sound even though organic production is high.

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72. AN INTRODUCTION TO THE STUDY OF MOVEMENT AND DISPERSAL IN ALLOGROMIA LATICOLLARIS ARNOLD

ZACH M. ARNOLD
Museum of Paleontology, University of California, Berkeley

The study of patterns and rates of movement and dispersal in laboratory populations of living Foraminifera is basic to the investigation of mechanisms of distribution of foraminiferal faunas. Although it is generally believed that the distribution of benthonic foraminifera is effected by external transporting agents or mechanisms, the potential for autonomous movement should be evaluated. It is conceivable that autonomous movement could play a critical role in population movements. Perhaps such independent movement could be responsible for the "portage" of a species or population across areas which were devoid of external transporting agencies. In such instances the more impressive distance coverage would still be brought about through the action of waves or currents, but the "portage" activities of the individuals would play a highly critical role.

Studies of movement can also contribute information on basic problems of ecologic relationships among individuals and populations. The responses of organisms to environmental gradients of many types can be investigated through laboratory observations. An understanding of the nature of such responses may aid in the eventual interpretation of many biogeographical and ecological problems.

A laboratory study of foraminiferal movements is much easier to conduct than a study in natural environments. The simple process of following the course of movement in such small organisms becomes bafflingly complex at the seaside. Large populations can be maintained in the laboratory for experimentation. The number of environmental factors involved can be greatly reduced and simplified, and rigorous control can be maintained over these, so that the interpretation of results is greatly facilitated.

A considerable degree of care must be exercised in arriving at conclusions and developing generalizations based on laboratory observations alone, however. All conclusions must be carefully qualified to prevent unwarranted generalization.

In spite of the feasibility and obvious advantages of laboratory studies of this type, few controlled observations on foraminiferal movements have been made. Cushman (1920) recorded observations on *Iridia diaphana,* but failed to state whether his records referred to the flow of protoplasmic granules within the pseudopodia or actual displacement of the entire animal along the substratum.

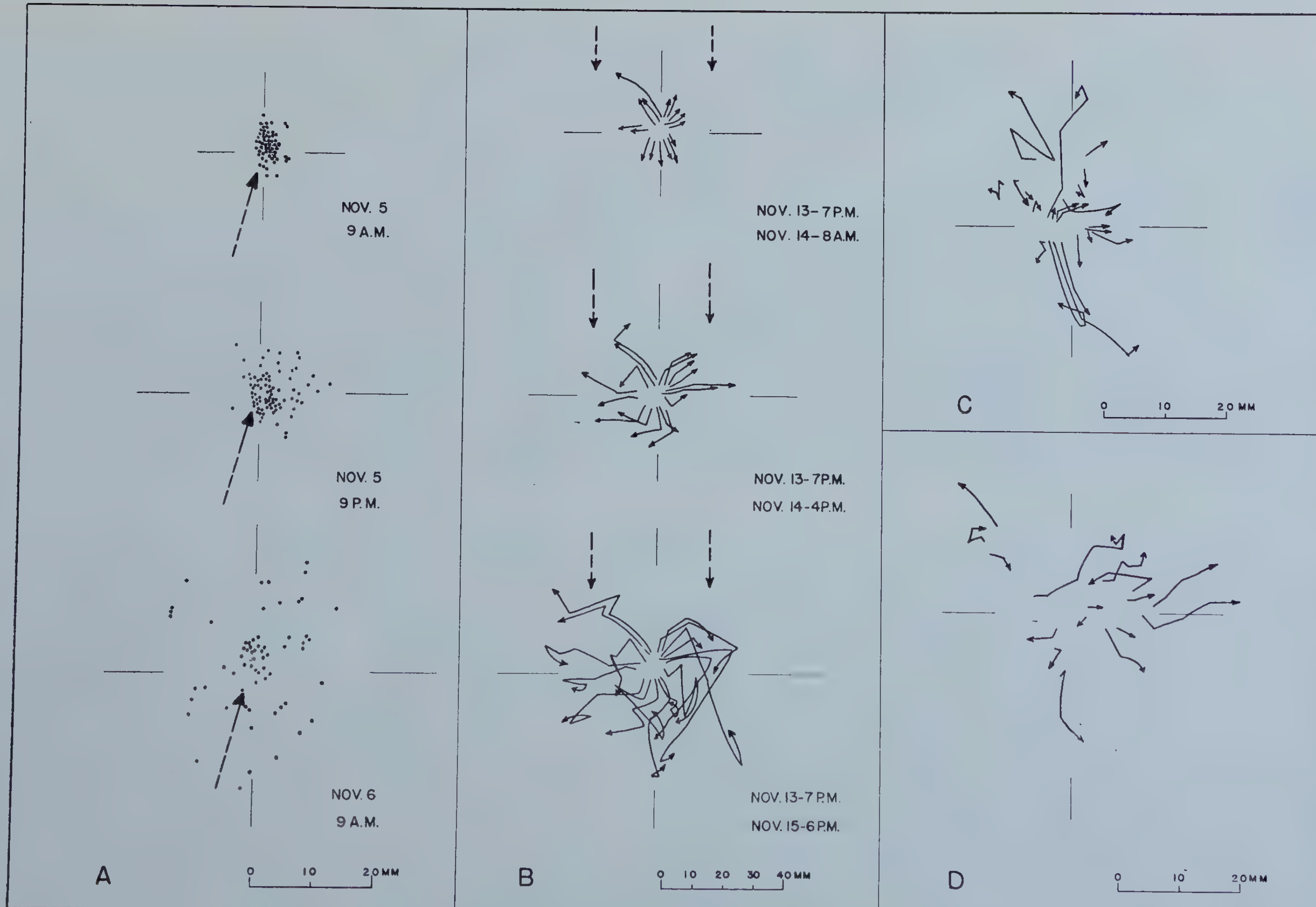
The species upon which these observations have been based is *Allogromia laticollaris* Arnold, a "chitinous"-shelled form belonging to the family Allogromiidae. All specimens were taken from laboratory cultures which were started from collections made in the intertidal waters of Saint Andrews Bay at Panama City, Florida. Adults of the species range from less than 100 to more than 400 microns in diameter, but the average is around 160 microns.

The movement data presented below were obtained through planned experimentation as well as routine observation of animals in cultures. In some of the experiments movement rates and patterns were carefully plotted from photographically recorded sequences. In these experiments the foraminifera were placed in a photographic enlarger, and at regular intervals exposures were made through the animal container, the position of the animals thus being recorded on sensitive paper. A series of such photographs was obtained, and individual as well as group movements were extracted through the use of transparent-overlay tracings.

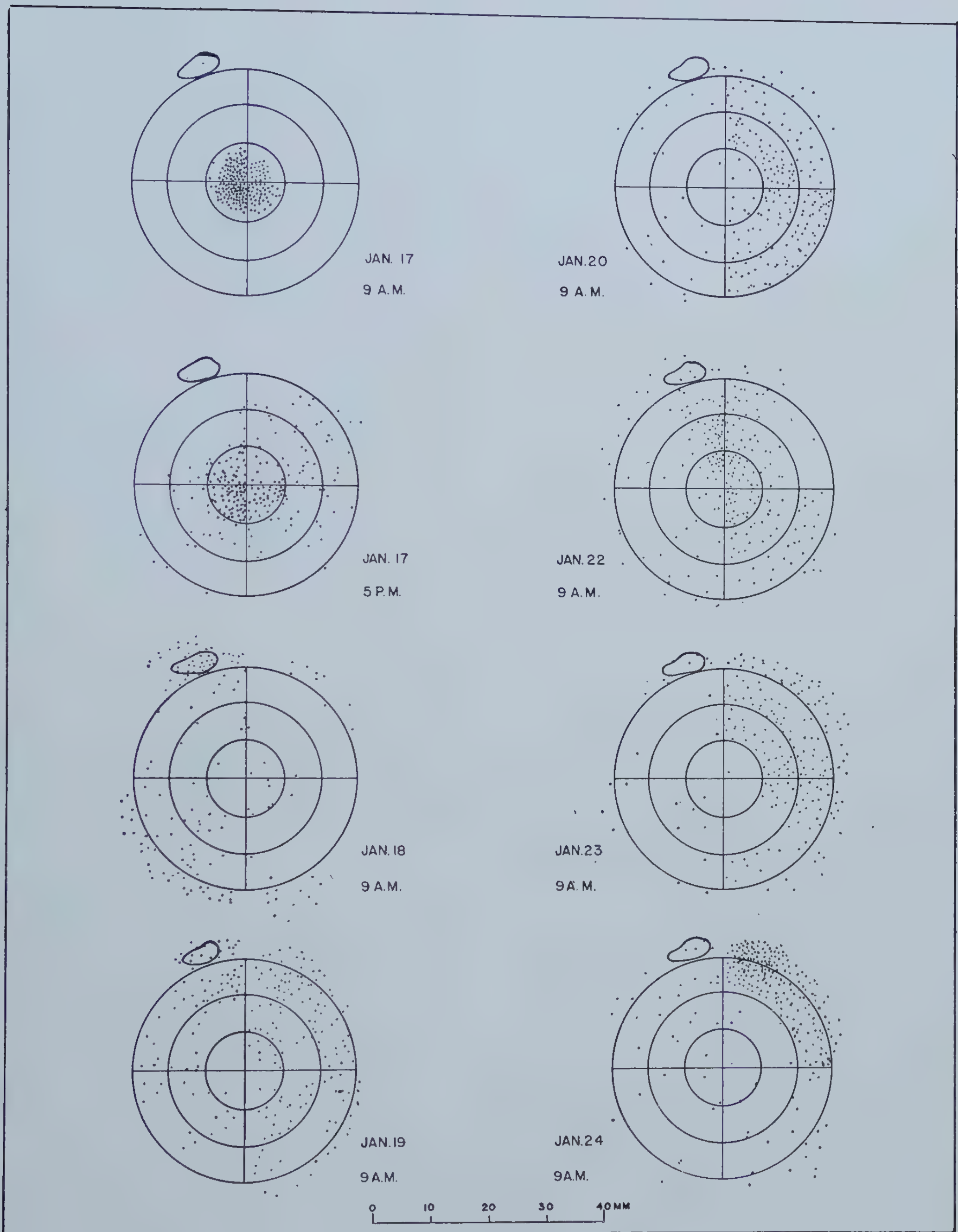
Movement is effected through the use of pseudopodia. Fine, threadlike and anastomosing extensions of protoplasm are spread out in all directions from the mouth of the animal. These become attached to the substratum over which the organism moves. Through mechanisms which are still completely baffling to the biologist, the organism is able to concentrate its pseudopodial effort in one direction and move toward the attached ends of these, while simultaneously withdrawing the pseudopodia which were stretched out behind. As a general rule the test remains in a fairly upright position above the moving mass of protoplasm, just as a snail shell does as the snail moves about.

The animals seem to be able to move along vertical surfaces as easily as along horizontal ones. The ease with which they could negotiate the 10-millimeter walls of glass retaining rings placed in their cultures prompted the experimental portion of this study of movement patterns and rates.

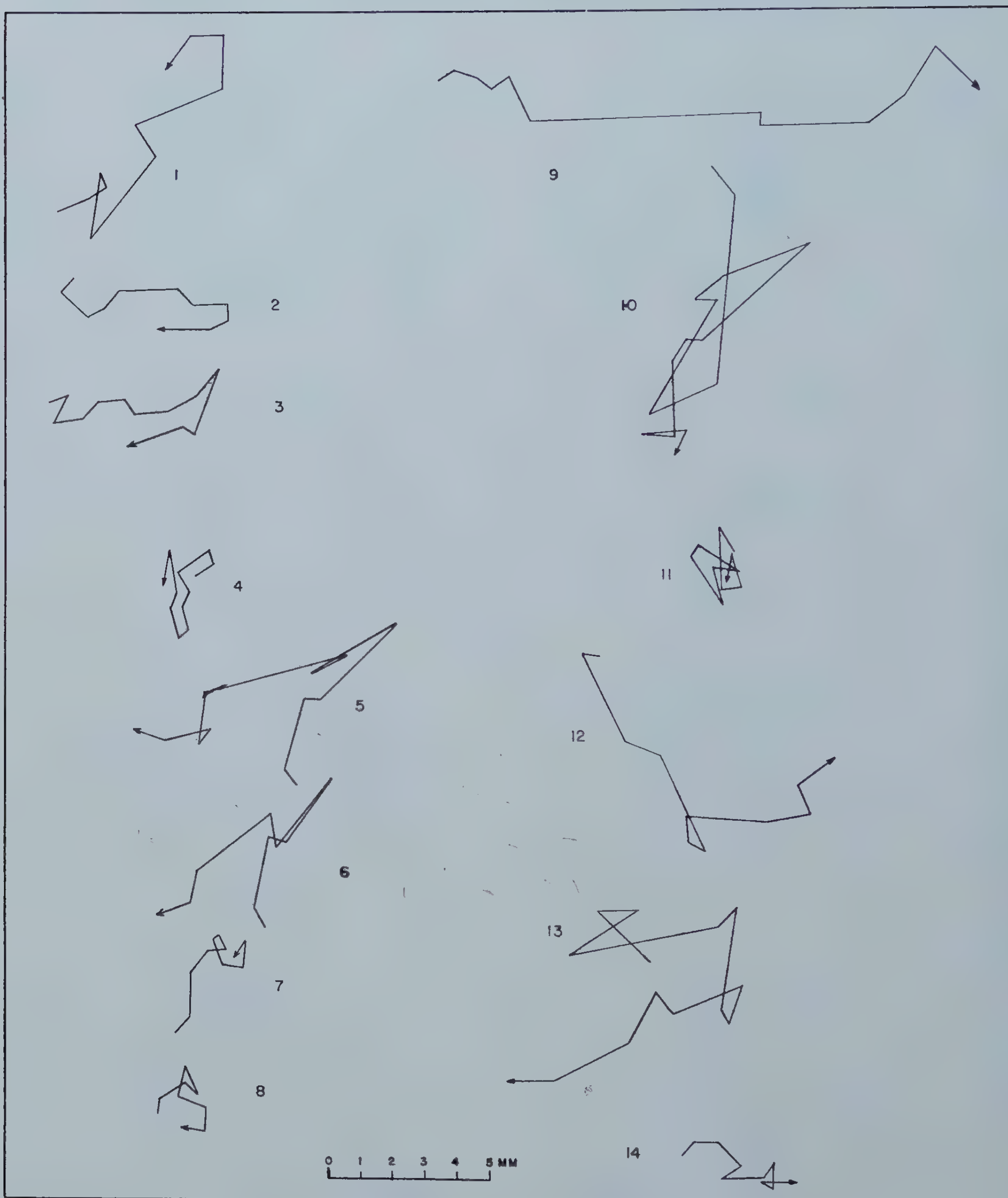
The rate of movement as well as rates of growth and reproduction generally vary inversely with the age of the laboratory cultures. Movement rates may at times be closely correlated with food supply, and it generally follows that a population in a well-balanced culture shows less movement than a population in a young culture. Although a population as a whole may be fairly stationary, a few individuals within the group may show active movement. This is particularly true of juvenile forms just following their escape from the



Text Figure 1. a) Movement sequences at 12-hour intervals, with illumination from lower left quadrant.
b) Movement paths at successive intervals, with illumination from upper quadrants.
c) and d) Dispersal and movement patterns.



Text Figure 2. Movement patterns of an experimental population. A mass of starch is indicated in the upper left quadrant.



Text Figure 3. Movement patterns in fourteen specimens of *Allogromia laticollaris* Arnold.

parent tests. Conversely, highly active populations may have some members which show no movement for protracted periods. Movement rates are generally quite independent for the members of any population, but exceptions do occur. In such cases two or more individuals may move about in close association and with actual protoplasmic contact.

The rate of movement may remain fairly constant for several hours, or it may be highly erratic. The rate varies with the individual animal and, no doubt, with the physiological condition of the animal at any given moment. In every experiment an initial lag period lasting from a few minutes to several hours was observed. Several explanations for this may be offered, but conclusive demonstration of the actual causative factor or factors is lacking. The lag may represent a period of recovery from injuries or shock sustained during the transfer to the experimental dishes.

The most rapid movement observed was 10 millimeters per hour, but this rate was sustained for only one hour. The average rates for three groups of animals, involving a total of 622 specimen-hours, were 2.5, 2.7, and 2.9 millimeters per hour.

One of the strongest tendencies revealed through a study of movement patterns is that of dispersal. The tendency is evident whenever a group of individuals is concentrated in a relatively small area. In 4-inch culture dishes populations are densest around the peripheral portions of the containers—an obvious result of dispersion. The explosive dispersion of individuals from areas of high concentration is shown by the movement sequences in Figures 1 and 2. In Figure 1a dispersal at 12-hour intervals is shown. The actual avenues of dispersal can be traced in Figure 1d for another group of animals observed at intervals over a 12-hour period. In this figure, as in others which show the actual paths of movement, the movement segments are represented by straight or broadly curved lines and sharp changes of direction. These segments do not reproduce in detail the minute waverings of the organism about the general path of its movement, but simply serve to connect, by the shortest possible route, the positions occupied by the animals at the time of successive "readings."

The dispersal phenomenon is strongly developed in young individuals as they escape from their parent tests after sexual or asexual reproduction. In older, stabilized cultures the only detectable movement may be that of juveniles moving away from their places of birth. After they have become distributed fairly evenly over the substratum they remain relatively stationary. In older cultures the animals are evenly spaced over the bottom, apparently setting up and abiding by a system of equitable distribution of pasturage which is reminiscent of the "territoriality" exhibited by many higher animals.

The pattern of movement developed by one individual generally bears no relationship to that shown by other individuals in the culture, with the exception, of course, of the general tendency toward dispersal. Individual movement paths may parallel one another occasionally, as can be seen in Figure 1b, but sooner or later a divergence occurs.

Movement patterns may be smooth and uni-directional, or they may be highly erratic. Some indication of the variation which is possible can be obtained from Figures 1b, 1c, 1d, and 3. If the available space is restricted an animal may cover an area previously covered by one or several animals, as shown in Figure 1b. An entire population may move about the bottom of a relatively sterile culture dish, diligently covering every square millimeter of surface area (see Figure 2).

This foraminiferan, through the activity of copious extensions of pseudopodia, rapidly accumulates large masses of food materials about its oral region and over its entire test. These activities are so effective that in luxurious diatom pastures the animals often bury themselves completely in accumulations of food. In immature cultures no foraminifera may be visible, but the entire culture bottom may be covered with balls of diatoms which, when ruptured, reveal one or several foraminifera forming the nucleus of the "micro-concretions."

In an effort to determine whether the animals could respond to the presence of food in the culture, one dish was set up with a mass of corn starch — a substance which they avidly ingest — in one quadrant, as indicated in Figure 2. A number of animals were then concentrated in the center of the dish and observed periodically for about one week. As the movement sequence shows, some of the organisms did find their way to the starch, a distance of approximately 20 millimeters from the center of the dish; however, the movements generally appear to be random in relation to the starch mass. The ones which did reach the starch within the first 24 hours apparently did so purely by accident, since just as many individuals reached the barren limits of the dish in the same period. Only a very few animals remained within the starched area for more than one day, and nearly all moved away to other areas of the dish before the conclusion of the experiment, indicating that there is not a strong or permanent attraction towards this material.

This experiment should not be taken to mean that the animals will perform similarly toward diatoms and other food organisms. It is as yet not known whether starch can be used as a source of nutriment by this or other foraminiferan species, although it is greedily ingested and retained by the animals. It is generally observable in cultures that the foraminifera congregate in areas rich in food materials, while few remain in barren spots on the substratum. The above experiment

may indicate, however, that the original discovery of the food material is nothing more than an accidental one and is the normal result of random dispersal of animals throughout the culture dish.

It is interesting to note, in passing, that some other factor or complex of factors than food seems to regulate population numbers in this species. Populations generally become stabilized at what appears to be an optimal level, but occasionally all restraint is lost and serious overpopulation and mass death occur. It is apparent at once that the maximal number which may occur in a culture is not the optimal number for a given environment. The factors which govern population numbers are probably highly complicated, but the discussion of these relationships lies beyond the scope of this presentation.

This species has shown no observable response to light intensities ranging up to 45 foot-candles. Incandescent and natural illumination have been employed for the experimental study of phototropisms, but no conclusive indication of either a negative or positive response has been obtained. The results of experiments involving incandescent illumination of 20 foot-candles and sunlight up to 45 foot-candles in intensity are shown in Figures 1a and 1b respectively. The direction of the energy source is indicated by arrows in the diagrams. Normal dispersal occurs and there is a slight indication of a negative phototropic response in the latter portion of the second figure, but the data do not warrant a conclusive statement at this time.

In a similar manner the experiments conducted to date indicate that the animals may be just as active during periods of darkness as during periods of illumination, but additional observations must be made before positive conclusions are justified.

Periods of inactivity and pseudopodial non-attachment occur, although the animals may be well supplied with food. They feed for a period, and then retract their pseudopodia and remain inactive for a while. As long as they are unattached they can be moved about over the bottom very easily, but as soon as they attach themselves by means of their pseudopodia a stronger force is necessary to dislodge them. This phenomenon might well provide a simple but effective means of removing supernumerary animals from an overpopulated environment, but the significance of it in nature must be investigated before such speculation can be substantiated or refuted.

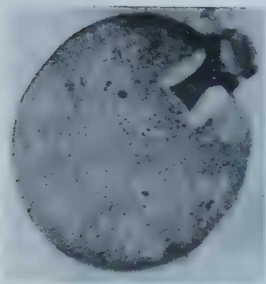
Shortly before reproduction these animals also retract their pseudopodia and lose their attachment to the substratum. A period of unattachment extending from several hours to a day or more precedes the liberation of young from the sexually -or asexually- reproducing adult. During this period the spherical individuals can readily be moved about by external factors. In an environment of mild current action such forms would be swept from one area into another prior to the liberation of juvenile forms. The dissemination of young could be effected by such transport and the mechanism might be important in the invasion and colonization of new areas.

Another possible distribution mechanism has been observed through the laboratory study of this species. In the cultures filamentous blue-green algae are frequently present in great abundance. These algae form heavy mats on the bottom of the dishes and support rich populations of foraminifera. If the algae are allowed to develop freely, large bubbles of gas accumulate under the mat and eventually force the entire mass to float to the surface of the water. The foraminifera embedded within and attached to the mat are carried to the surface also, and many of them continue to flourish in the partially-submerged algal "rafts." If such mats formed in natural environments they too could float to the surface and become valuable rafts for the transport of their contained foraminiferal popula-

EXPLANATION OF PLATE 3

FIGS.

1. Typical adult of *Allogromia laticollaris* stained to show entosolenian tube and collar. × 120.
2. Actively feeding specimen with pseudopodia extended. Photograph taken with phase contrast microscope. × 40.
3. Typical adult with protoplasmic elements stained. Nucleus in lower portion of test, large food inclusion in middle portion of right side. × 150.
4. Specimen about to undergo asexual reproduction by terminal budding. Each "segment" has a single nucleus. × 200.
5. Lobed specimen showing two mouths in the right-hand lobe and two nuclei in the opposite lobe. × 150.
6. Lobed specimen with mouth in three of the four lobes. × 150.
7. Lobed specimen with two nuclei. × 200.
8. Lobed specimen. × 200.
9. Specimen showing seven unequal lobes and five nuclei. × 200.
10. Oval specimen with mouths at opposite poles. × 100.
11. Elongate specimen with three mouths, two terminal and one sub-median. × 100.
12. Elongate specimen with pseudopodia extended. Lower end obscured by food mass. Two terminal mouths present. × 100.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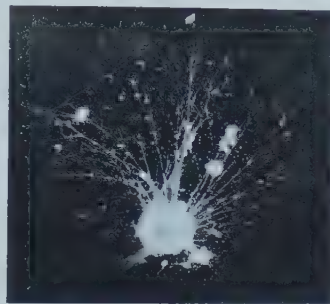
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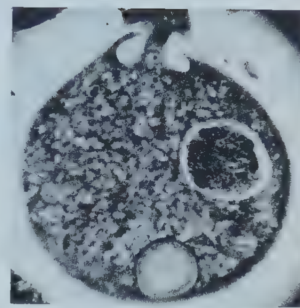
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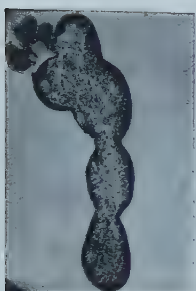
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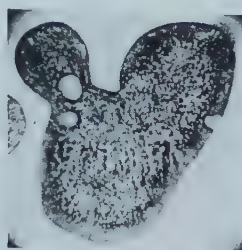
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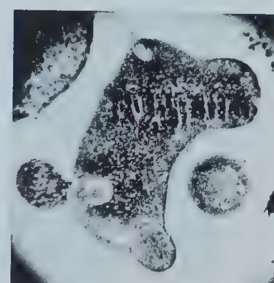
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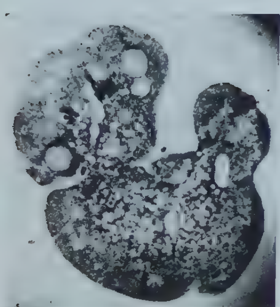
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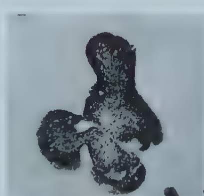
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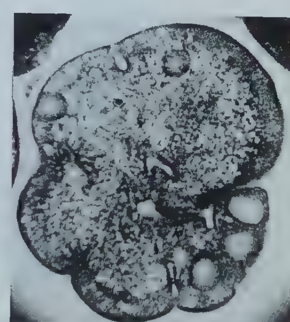
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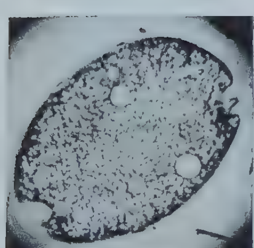
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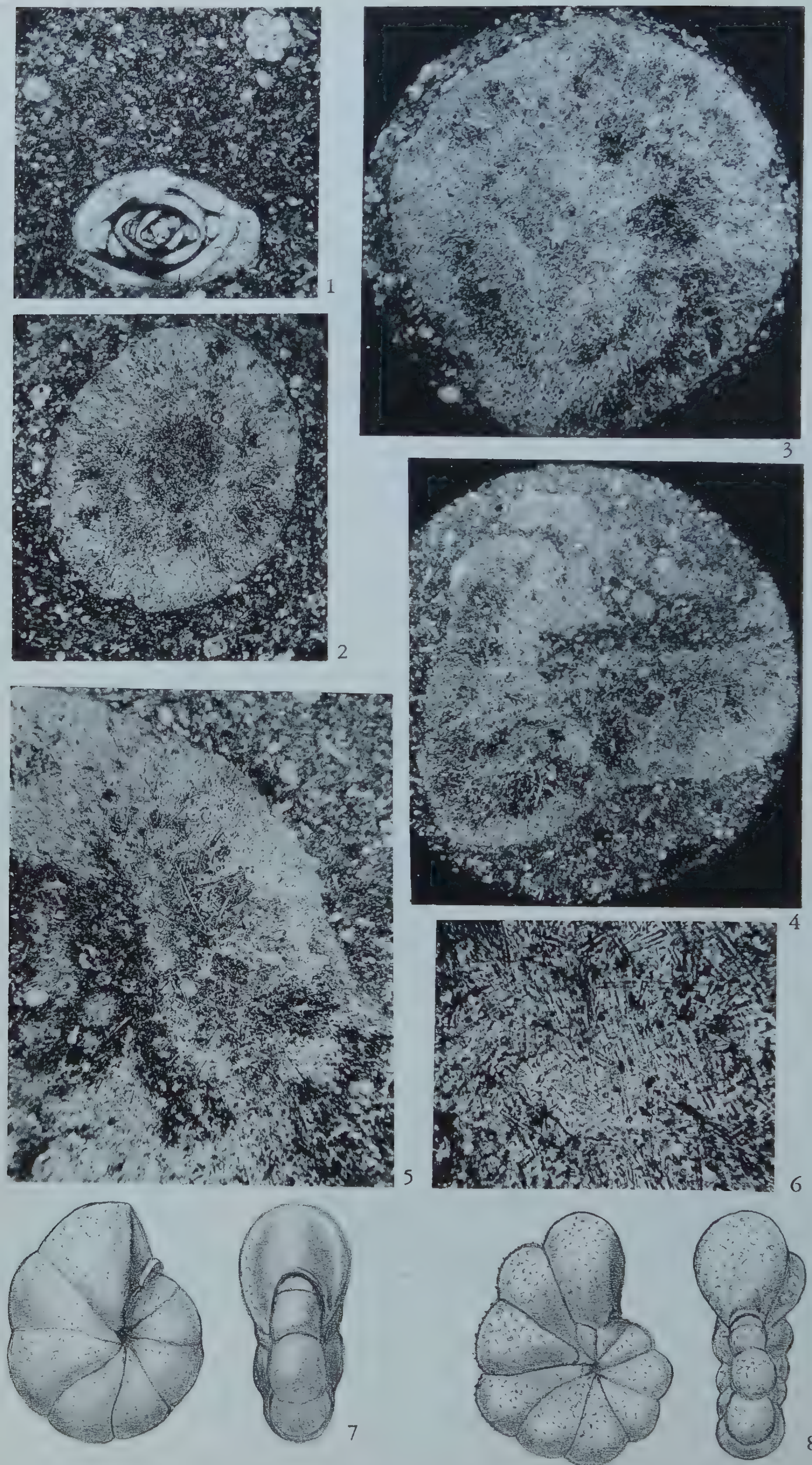
Phot. by Z. M. Arnold

Arnold: *Allogromia laticollaris* Arnold



Avnimelech: *Bathysiphon* in Eocene of Israel

tions. The general significance of this mechanism in nature must be investigated by further experimentation and observation in natural environments.

The above observations serve to illustrate the nature of the data which can be obtained from the laboratory study of living foraminifera. Many of the results are tentative and inconclusive, some of the observations require supporting evidence, and all of the studies require further expansion and extension to other species. It is hoped that these efforts will spark the interest of other students of the foraminifera and eventually increase our understanding of the biology and paleontology of the Order.

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73. TWO NEW SPECIES OF HAPLOPHRAGMOIDES FROM THE LOUISIANA COAST

Harold V. Andersen
Louisiana State University

Introduction.—The two new species of *Haplophragmoides* described in this paper were recovered from sediments deposited in brackish water environments, a marsh sample from Barataria Bay, Louisiana (Sample BB-1, collected by W. W. Anderson, Conservation Department, New Orleans, Louisiana), and a bottom sample from Dog Lake, 20 miles south of Dulac, Louisiana (Sample DL-1, collected by S. E. Roper, former geology student at Louisiana State University). The species are described to satisfy a nomenclatural need in the current study of the foraminiferal faunules from the lower Mississippi River delta being concluded by the writer.

Acknowledgments.—The writer is indebted to H. V. Howe, Director, School of Geology, Louisiana State University, for sharing the sample collected for him by W. W. Anderson; to S. E. Roper for the samples collected by him for the writer; to G. Arthur Cooper and Alfred R. Loeblich, Jr., U. S. National Museum, for the use of the U. S. National Museum types and equipment; and to Ruth Todd, U. S. Geological Survey, for the opportunity to compare the specimens with material from the Gulf of Paria, Trinidad.

Family LITUOLIDAE
Genus **Haplophragmoides** Cushman, 1910
Haplophragmoides wilberti Andersen, n. sp.

Plate 4, figures 7a, b

Description.—Test free, medium size, planispiral and completely involute; wall finely arenaceous with much cement; surface smooth and glossy; chambers slightly inflated, increasing gradually in size as added, succeeding chambers reaching almost to the axis of coiling leaving a slight open umbilicus, 7 to 8 chambers in the last whorl; final chamber with a slight depression par-

EXPLANATION OF PLATE 4

Figs.		Page
1.	Siliceous limestone with *Radiolaria*, spicules of *Silicispongiae*, *Sigmoilina* and *Globorotalia*. Lower Eocene, N of Merhavia (Affula), Israel. × 85.	23
2.	Siliceous *Radiolaria*-limestone with a cross-section of *Bathysiphon* showing arrangement of spicules nearly perpendicular to surface. Width of tube about ⅓ of diameter of test. Tube filled with fine rock material in which a *Radiolaria* is seen. Some parts of the wall, mainly in the middle part, near the surface or even on the surface, show black spots of small secondarily filled alveolar cavities inside the wall. × 85.	23
3.	Oblique section of a larger specimen. Cavities in wall (grey or black) arranged near periphery (upper part of test) at nearly regular intervals, several of them interconnected. × 85.	23
4.	Oblique section of a fragment of a tube which has probably collapsed in the direction of the acute angle of the test (dark elongated spot visible). Spicules mostly normal to surface, but also scattered in other directions. × 85.	23
5.	Fragment of another specimen, outer surface rugose, inner surface irregular with some spicules protruding from wall. Some cavities of the wall visible in left corner. × 140.	23
6.	Fragment of test showing texture: small spicules mostly parallel but diagonally interwoven with larger spicules in some of which inner canal is visible. × 390.	23
7.	*Haplophragmoides wilberti* Andersen, n. sp. a, side view of holotype (H. V. Howe Collection No. 4209); b, edge view. × 75.	21
8.	*Haplophragmoides manilaensis* Andersen, n. sp. a, side view of holotype (H. V. Howe Collection No. 4503); b, edge view. × 75.	22

allel to each lateral margin and with a slight lip at its base; sutures distinct, slightly depressed, typically straight but occasionally with a slight sigmoid curve; periphery broadly rounded, slightly lobulate; aperture a low arched opening at the base of the final chamber.

Dimensions.—Maximum diameter of holotype 0.48 mm.; maximum thickness 0.23 mm.

Occurrence.—Holotype from Dog Lake, 20 miles south of Dulac, Louisiana, Sample No. DL-1. Also present in a marsh sample from Barataria Bay and a beach sample from Southwest Pass of the Mississippi River, 1 mile south of Burrwood, Louisiana.

Remarks.—Variations in the external appearance of the test has been noted in this species. In the marsh sample from Barataria Bay, the individual specimens range from those with much cement in the test to specimens with very thin, chitinous appearing walls. The thin-walled specimens are similar to *Labrospira salsa* Cushman and Bronnimann from the Gulf of Paria, Trinidad, but lack the aerial aperture of *L. salsa.* The thick-walled, well cemented specimens most typical of the species resemble *Haplophragmoides subinvolutum* Cushman and McCulloch from the Pacific coast but lack the pronounced sigmoid sutures and overhanging lip of *H. subinvolutum.*

This species is named in honor of Louis J. Wilbert, School of Geology, Louisiana State University.

Types and repositories.—Holotype (H. V. Howe Collection No. 4209) deposited in the Geological Museum, Louisiana State University, Baton Rouge, Louisiana. Unfigured paratypes are deposited in the U. S. National Museum, Washington, D. C.

Haplophragmoides manilaensis Andersen, n. sp.
Plate 4, figures 8a, b

Description.—Test free, medium size, planispiral, initial chambers involute, adult chambers in some specimens tending to become evolute; wall finely arenaceous with little cement; surface with a slightly roughened exterior; chambers inflated near the peripheral margin, increasing very gradually in length but notably in width as added, 8 to 10 chambers in the last-formed whorl; final chamber with an incipient lip at its base, succeeding chambers reach almost to the axis of coiling leaving a slight open umbilicus; area surrounding umbilicus greatly depressed relative to the peripheral margin; sutures straight, slightly depressed near the axis of coiling, but deeply depressed near the peripheral margin; periphery broadly rounded, lobulate; aperture a narrow arched opening at the base of the final chamber.

Dimensions.—Maximum diameter of holotype 0.50 mm.; maximum thickness 0.20 mm. Other specimens range in diameter from 0.70 mm. to 0.42 mm.

Occurrence.—Holotype from Barataria Bay at Manila Village, Louisiana, Sample No. BB-1. Also present in sediment from Dog Lake, 20 miles south of Dulac, Louisiana. Favored habitat of the species appears to be the inland brackish-water bays and lakes connected with the Gulf of Mexico through a series of constricted passes or tidal channels.

Remarks.—This species resembles *Haplophragmoides mauricensis* Howe and Ellis from the Cook Mountain of Louisiana. The principal differences between the two species are as follows: the size of the test and chambers in *H. manilaensis* are larger and proportionately broader relative to the size of the test in *H. mauricensis.* The initial planispiral coil is sufficient to distinguish the warped and distorted specimens from *Trochamminita irregularis* Cushman and Bronnimann.

Types and repositories.—Holotype (H. V. Howe Collection No. 4503) and unfigured paratype (H. V. Howe Collection No. 4211) deposited in the Geological Museum, Louisiana State University, Baton Rouge, Louisiana. Unfigured paratypes are deposited in the U. S. National Museum, Washington, D. C.

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74. NORTHERN ALASKA INDEX FORAMINIFERA: A CORRECTION

Helen Tappan
U. S. Geological Survey, Washington, D. C.

Illustrations of two species were accidentally interchanged on the plate accompanying the article, "Northern Alaska Index Foraminifera" (Contr. Cushman Found. Foram. Research, vol. 2, pt. 1, pl. 1.). The plate had been damaged while held in Survey files awaiting a decision on stratigraphic terminology used elsewhere in the paper. It was remounted by the author just before mailing it for reproduction, and the illustrations of the two species were somehow mixed. For this reason, the legend to the plate and the figure reference in the specific description do not agree with the actual figures.

Figs. 1a, b, as shown, are of *Lingulina alaskensis*, n. sp. and figs. 2a, b, as shown, are of *Nodosaria shublikensis*, n. sp. However, in order that the figures agree with the plate description and text, the figures 1a and 2a and 1b and 2b should be interchanged, on the plate.

Both species are correctly designated in two later publications: Tappan, H., 1951, in Payne, T. G. and others, Geology of the Arctic Slope of Alaska, U. S. Geol. Survey Oil and Gas Invest. Map OM-126, sheet 3, fig. 21 (*Nodosaria shublikensis*, figs. 16a, b; *Lingulina alaskensis*, figs. 17a, b).

Tappan, H., 1951, Foraminifera from the Arctic Slope of Alaska, General Introduction and Part 1, Triassic Foraminifera, U. S. Geological Survey Prof. Paper 236-A (*Nodosaria shublikensis*, pl. 3, figs. 1-4; *Lingulina alaskensis*, Pl. 4, figs. 18-22). In this reference, sent to press while the first paper was still in the Survey files, the synonomy also erroneously cites the plate and figure numbers to the original reference, as it followed the text and original plate layout, and the mistake on the plate was not caught until after the article was published.

75. OCCURRENCE OF THE GENUS BATHYSIPHON IN THE EOCENE OF ISRAEL

M. Avnimelech
Hebrew University, Jerusalem

ABSTRACT—Occurrence of **Bathysiphon** in the Lower Eocene of Israel is recorded. On the basis of several figured thin sections, the texture of the test-wall is described.

In some areas of Israel there occur in several layers of lower Eocene relatively big tubes of the arenaceous genus *Bathysiphon*. These are simple tube-like forms, 2-3 mm. up to more than 10 mm. long and less than 1 mm. to 2 mm. in diameter. The test is siliceous, and of characteristically brown color. Because of good preservation of the specimens it was possible to examine in detail the fine texture hitherto only insufficiently known.

The areas where this genus occurs are situated between the Carmel and the Nazareth Hills. One locality is in the south-west corner of the Giveath-Hamoreh (Nebi-Dahi or "Little Hermon") Mountain, north of Merhavia, a village near Affula. Another locality is south-east of Mount Carmel, between the villages of Yokneam and Mishmar-Haemek. The Lower Eocene beds consist mostly of hard, silicified, grey bituminous limestone or of white, slightly chalky limestone containing mostly *Radiolaria*, few *Globorotalia* and isolated *Miliolidae (Sigmoilina)* (Pl.. 4, Fig. 1). The *Bathysiphon* specimens are megascopically visible as brown, hard fragments of tubes, up to 10 mm. long and ½ mm. broad, with smooth polished surface. They often show a typical longitudinal furrow on both sides, caused, according to various authors, by the collapse of the test.

Thin sections (Pl. 4, Figs. 2-6) show the wall to be almost entirely constructed of tiny sponge-spicules, probably *Monactinellidae*. Most of the spicules are arranged perpendicular to the surface of the tube, but many are directed at random. Higher magnification (140 to 390×) suggests that smaller and larger fragments of spicules are interwoven. Some sections reveal a delicate canal inside the spicules. In the rock itself no megascopic remnants of *Porifera* were observed, although numerous isolated spicules are scattered in it. The texture of the test of *Bathysiphon*, however, shows the actual presence of *Silicispongiae*.

A striking feature of the wall-texture is the presence, mostly in the midst of the wall but also near to the outer surface, of irregular alveolar cavities, secondarily filled by compact, probably siliceous material. In some sections (Pl. 4, figs. 2-5) these cavities occur in more

or less regular intervals, sometimes connected one with another, presenting a roughly wavy pattern. A diagonal section of the tube, shown in Plate 4, Figure 3, suggests that the cavities are of labyrinthic shape.

These interstitial cavities may simply have a mechanical function, namely the saving of energy needed for the construction of the test, thus diminishing its weight. Their arrangement along the tube may be the main cause for the typical longitudinal collapsing and furrowing of the test during fossilization.

Shape and proportions of the *Bathysiphon* specimens in the Lower Eocene of Israel are similar to those of *B. taurinensis* Sacco from the Aquitanian (Upper Oligocene) and Miocene of Italy. *"Bathysiphon" carapitanus* Hedberg, recently assigned to the genus *Psammosiphonella* Avnimelech (1952), from the Middle Tertiary of Venezuela is externally also similar. According to the original diagnosis given by Hedberg, this species, however, is entirely arenaceous without containing sponge-spicules in its wall-material, and, therefore, can not be compared with our species.

The lithological properties of the Lower Eocene beds in the region between the Carmel and the Nazareth Hills, namely siliceous bituminous limestone containing mostly *Radiolaria* together with *Bathysiphon* and sponge-spicules (probably monactellinid) distinctly indicate a bathyal environment with a depth of water probably not less than 1000 meters. This seems to be the usual depth of occurrence of true *Bathysiphon* in temperate and warm seas where temperature is stable and low. This habitat also seems to be preferred by *Silicispongiae.* In colder seas, however, *Bathysiphon* and its relatives may live in environments of shallower depth.

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76. PALEONTOLOGY AND THE STUDY OF VARIATION IN LIVING FORAMINIFERA

Zach M. Arnold
Museum of Paleontology, University of California, Berkeley

The study of variation in living Foraminifera can aid the paleontologist in evaluating the taxonomic importance of morphological features. Studies conducted on lineages of known ancestry can contribute directly to the understanding of taxonomic and evolutionary relationships within the group.

As an example of the type of problem which could be investigated by such studies, mention might be made of the variation shown by apertural characters in certain of the Buliminidae. California Miocene specimens of the subgenus or genus *Uvigerinella* show two types of apertures. Most of the specimens possess a round mouth opening of the type found in *Uvigerina.* A small number, however, have a lateral furrow which cuts through the apertural rim and reminds one of the comma-shaped aperture of *Bulimina,* the presumptive ancestral type. The paleontologist would like to know whether one or two species is involved in this variation. Perhaps the forms possessing the lateral furrow are transitional between the *Bulimina* and *Uvigerinella* types in an evolutionary sequence, or, perhaps the observed variants are completely independent in their evolution and heredity. The paleontologist would like to know whether either of the variants breeds true and is, therefore, heritable, or whether the variation has been induced through environmental pressure and is not passed on from one generation to the next. It would be interesting to isolate a living specimen of *Uvigerinella* and study its progeny through several generations in order to determine just what range of variation occurs in its apertural characters. The range could be determined for several lineages, and appropriate taxonomic adjustments could be made on the basis of the results obtained.

An investigation of this type has been made on certain variations occurring in a primitive, "chitinous"-shelled foraminiferan from the Florida waters of the Gulf of Mexico. The species studied was *Allogromia laticollaris*[1], a form not yet known from the fossil record. It belongs to the type genus of the family Allogromiidae, from which all foraminifera presumably have been derived, and possesses much of the plasticity that the paleontologist has assumed for primitive ancestral types.

The specimens used in this study were obtained from lineages maintained in laboratory cultures since June 1946. The original collections were made in Saint Andrews Bay in the vicinity of Panama City, Florida (Arnold, 1948). The typical individual has an ovoidal to spherical test with a single mouth opening. A section through the test and protoplasmic body is illustrated in Plate 3, Fig. 1, and shows the prominently

[1] The original specific designation, **laticollare** (Arnold, 1948), does not agree with the genus in gender and should be changed to **laticollaris.**

stained entosolenian tube through which protoplasm flows as the animal feeds or moves about. Such a feeding animal with an extensive spread of anastomosing pseudopodia is pictured in Plate 3, Fig. 2. The section illustrated in Plate 3, Fig. 3 has been stained to show the protoplasmic elements, including the nucleus and a large food body. The figure shows the intra-test protoplasm, a mass of circumoral protoplasm from which the pseudopodia are formed, and the connecting isthmus of protoplasm which flows through the entosolenian tube. The funnel-shaped aperture which lies within a prominent collar-like extension of the tube frequently develops radiating furrows which are reminiscent of the radiate aperture of the Lagenids. The early origins of the nodosarine chamber arrangement are strongly suggested by the linear constriction of buds in asexually reproducing individuals (Plate 3, Fig. 4).

The morphological variations which have been investigated thus far include: (1) number of apertures, (2) over-all shape, and (3) flattening, since the fixation of any one of these variants in an hereditarily distinct lineage could lead to the evolution of types which would be treated as separate units in the existing taxonomy of the family. Several other characters and variants have been observed, but no attempt has been made to analyze these. One of the most prominent variants encountered in these studies is that of lobation. Sections of lobed individuals are seen in Plate 3, Figs. 4 through 9, and indicate something of the wide range of variation in this character. Most highly lobate specimens are found to have accessory apertures, as can be seen in Plate 3, Figs. 5, 6, and 8. Other characters which are known to show considerable variation are: structure, shape and position of apertures, number of radiating apertural furrows, length and thickness of entosolenian tube, and over-all size of individuals throughout all stages of growth.

In large, wild populations of this species one can generally find a few animals which have two, three or more mouths, although the normal form has but a single mouth opening. Individuals in Plate 3, Figs. 5, 6, 8, 10, 11, and 12 have accessory apertures. In order to determine something of the nature of the accessory aperture variation a triple-mouthed individual was isolated and observed for several days. Within a week the young began to emerge from the parent test and were seen to have only a single mouth — the progeny of a triple-mouthed parent!

A number of experiments of this type were conducted, but multiple-mouthed individuals repeatedly reverted to the normal condition in subsequent generations. A series of more than 500 experiments involving normal and abnormal parents and a wide variety of laboratory environments has shown: (1) that multiple-mouthed progeny appear with a fairly constant, though relatively low, frequency in most lineages; (2) that the number of mouths does not appear to vary with the environment; (3) that this variation is passed from one generation to the next in some manner, although it, like haemophilia and color-blindness in man, is not always expressed in each generation.

By using the same procedures which have been developed on this pilot species it should be possible to establish controlled lineages of a species of *Robulus*, with its accessory apertural slit, and determine whether or not successive generations possess the extra slit. In a similar manner lineages of *Lenticulina* could be studied to see how faithfully the single aperture appears in its progeny. Through such observations one could learn much about the taxonomic reliability of accessory apertures in the Lagenid stock. Throughout the Order numerous examples of variation in apertural characteristics have plagued modern foraminiferal taxonomy. Studies of this type could aid in clarifying the taxonomic significance of these characters.

The study of a second class of variable characters involving gross body shape has produced interesting results. In wild populations considerable variation in over-all shape occurs. The normal animal is spherical to oval, but fusiform, triangular and quadrangular individuals appear with about the same frequency (approximately 0.5 to 5% of the cases) as did forms with multiple apertures. The shape variations, in fact, are generally associated with apertural anomalies: fusiform types have a mouth at each end, triangular forms have a mouth at each apex, and so forth. Experimental observations of the progeny of isolated individuals have shown that these variations follow the pattern revealed for accessory apertures, and it seems reasonable to believe that similar determining factors are responsible for their expression.

Occasionally populations appeared which showed large numbers of flattened, discoidal specimens. The offspring of these creatures at first were plump, normal animals, but if they were allowed to remain in the same dish with their parents they too became discoidal adults. Closer examination showed that in such cases of flattening a heavy network of microscopic, filamentous algae had formed in the dish and had actually overgrown the foraminifera. Flattening appeared to be due directly to the downward pressure exerted by the rapidly multiplying algal filaments. The young animals readily escaped through the algal entanglements, but before they reached maturity were overgrown by the expanding network and flattened, just as their parents had been before them.

A similar, but much more strongly developed, flattening was observed when the species was grown on a semi-solid culture medium, such as agar, instead of in sea-water. But here, as in the previous case, the abnormality was not passed on to subsequent generations

unless the young were allowed to remain in the parental culture dish, and here, too, the normal shape could be restored by transferring the animals back to their sea-water cultures.

Of the three characters studied, then, only one—flattening—seems to be a response to environmental conditions. Successive generations may show flattening only if the causative environmental factors remain unchanged, since this anomaly is not transmitted from parent to offspring. The other two characters—variation in body-shape and in number of accessory apertures—do not vary with environmental changes, but appear to be heritable, and are, therefore, of taxonomic significance.

The above observations show that the number of apertures is not constant in this species of *Allogromia*. Although the typical individual is single-mouthed, progeny with accessory apertures are not infrequent in pure-line cultures. The genus *Allogromia*, as it was established by Rhumbler (1903), contains only species possessing a single mouth opening. The occurrence of accessory apertures should be recognized and included in future descriptions of the genus.

The position of the mouth opening and entosolenian tube ("Pseudopodienstiel" of Rhumbler) is used in separating the genus *Lieberkühnia* from *Allogromia* (Rhumbler, 1903). The aperture is supposedly subterminal in the former and terminal in the latter. Figures 5, 6, 11, and 12 of Plate 3 show specimens taken from cultures of *Allogromia laticollaris* and demonstrate the inadvisability of using this character in distinguishing genera within the family. The laboratory examination of cultures of other members of this family is planned, and the results of these observations may aid in the eventual revision of the genera and species within this "primitive" foraminiferan family.

The methods that have been developed for this study could be applied to the study of most other groups of foraminifera in which there are living species. The extension of studies of this type to other groups should aid the paleontologist in the taxonomic evaluation of many troublesome variations in test morphology.

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77. LOWER CRETACEOUS FORAMINIFERA FROM THE GREAT ARTESIAN BASIN, AUSTRALIA[1]

IRENE CRESPIN
Canberra, Australia

ABSTRACT—The distribution of Lower Cretaceous deposits in the States of Queensland, New South Wales, South Australia and Northern Territory, is closely linked with the boundaries of the Great Artesian Basin. Foraminifera have been found in many outcrops and bores throughout the Basin, and some of these are described herein. Systematic descriptions of eighteen new species and one new variety are given and previously described species are discussed and re-figured.

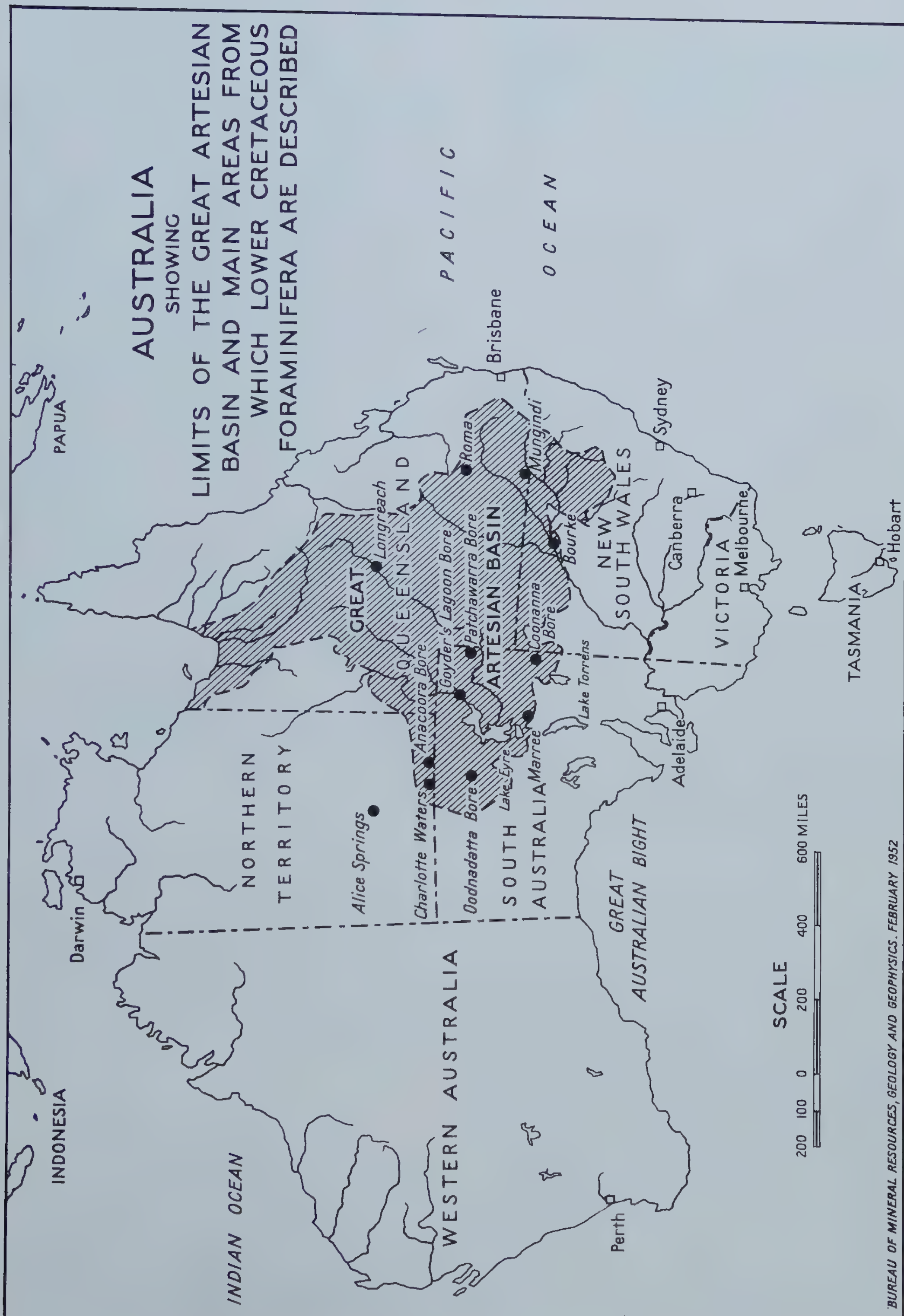
INTRODUCTION

The distribution of Lower Cretaceous sediments in Queensland, northern New South Wales, northern South Australia and southern Northern Territory is closely linked with the Great Artesian Basin which covers an area exceeding 500,000 square miles. The Basin includes some of the driest parts of the Australian Continent and many bores have been drilled in it to tap the main aquifers which exist in the Jurassic rocks underlying the Cretaceous. The potential water supply from these beds has been studied by the Committee of Investigation inquiring into the nature and structure of the Great Artesian Basin. This Committee operates in the States of Queensland, New South Wales and South Australia. The limits of the aquifers are now reasonably well defined, and the recognized boundaries of the Artesian Basin are shown in Text Figure 1, which is based on a map in the report of the Queensland Committee of Investigation, 1945.

Little work has been done on the microfaunal content of the sediments in the northern part of the Basin, but material has been examined from many bores in the southern and south-western part and some of the localities are shown in Text Figure 1. In addition to the examination of bore samples, a considerable amount of surface material from the vicinity of Roma, in southern central Queensland has been examined, and this has helped in the correlation of subsurface deposits.

Many of the bores in north-eastern South Australia were drilled to a depth of more than 5,500 feet (Jack, 1930) and foraminifera were found in some of them at considerable depths. The lowest record of foraminifera in the Patchawarra Bore was at 5,100 feet and in Goyder's Lagoon Bore at 4,500 feet.

[1] Published with permission of the Director of the Bureau of Mineral Resources, Geology and Geophysics.


AUSTRALIA
SHOWING
LIMITS OF THE GREAT ARTESIAN BASIN AND MAIN AREAS FROM WHICH LOWER CRETACEOUS FORAMINIFERA ARE DESCRIBED
PACIFIC
OCEAN
INDIAN OCEAN
INDONESIA
PAPUA
Darwin
NORTHERN TERRITORY
WESTERN AUSTRALIA
SOUTH AUSTRALIA
QUEENSLAND
NEW SOUTH WALES
VICTORIA
TASMANIA
GREAT ARTESIAN BASIN
GREAT AUSTRALIAN BIGHT
Alice Springs
Charlotte Waters
Oodnadatta Bore
Anacoora Bore
Goyder's Lagoon Bore
Patchawarra Bore
Coonanna Bore
Marree
Lake Eyre
Lake Torrens
Longreach
Roma
Mungindi
Bourke
Brisbane
Sydney
Canberra
Melbourne
Hobart
Adelaide
Perth
SCALE
200 100 0 200 400 600 MILES
BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS. FEBRUARY 1952

The bores in the Great Artesian Basin have been drilled essentially for water and not for scientific purposes. Consequently complete sections have not been preserved. However, enough evidence is now available to show that a characteristic assemblage of foraminiferal species is present throughout. This assemblage is also found in the extensive surface deposits in the Roma area. Arenaceous forms dominate the assemblages and the tests are usually crushed or deflated. Calcareous tests, however, are better preserved. Howchin (1884) noted this characteristic preservation and it is noteworthy that the same condition of preservation of arenaceous tests exists in some of the Lower Cretaceous deposits of America.

As far as is known, the majority of species described in this paper are restricted to Lower Cretaceous deposits, which, according to the mega-fossils, can be correlated with beds in the Great Artesian Basin. However, small species such as *Globigerina cretacea*, occur in the Upper Cretaceous rocks throughout the world.

The specimens described in this paper were examined by Mrs. Helen Loeblich of Washington, D. C. during a recent visit of the writer to the United States of America. She confirmed the opinion that the majority of species were new, although there was considerable resemblance to American Lower Cretaceous forms. Some of the species described by the writer in 1944 are now refigured and in some cases the generic determinations have been revised. Thirty species are described. Eighteen of these are new and there is one new variety. A complete list of localities from which the various species have been found, is not given at the end of the description of each species. In many cases the occurrences are numerous as the distribution of some species is widespread throughout the Great Artesian Basin.

Bore samples were made available to the Bureau of Mineral Resources, Geology and Geophysics for micropalaeontological examination through the courtesy of the Water Conservation and Irrigation Commission of New South Wales, of the Department of Mines, Adelaide, South Australia and of Roma Blocks Oil Company N. L., Roma, Queensland. Some samples from earlier bores in the vicinity of Longreach, Central Queensland were submitted by Oil Search Limited, Sydney, New South Wales. The surface material from Roma, central southern Queensland was collected chiefly by the writer and some specimens were sent for examination from Hughenden, Central Queensland by Associate Professor F. W. Whitehouse, University of Queensland, Brisbane. The Director of the South Australian Museum, Adelaide, kindly permitted the writer to study specimens in the Howchin collection at that institution.

All types are in the Commonwealth Palaeontological Collections at Canberra. The excellent illustrations were prepared by H. S. Edgell of the Bureau of Mineral Resources, Geology and Geophysics.

PREVIOUS LITERATURE

Little literature on Lower Cretaceous foraminifera in Australia is available and many of the early recorded species were referred to Recent forms.

The earliest discovery of microfossils in the Lower Cretaceous deposits of the Great Artesian Basin was made in Queensland by Charles Moore (1870) when he found foraminifera in sediments at Wallumbilla Creek, which is crossed by the Great Western Railway, 294 miles from Brisbane and about 24 miles east of Roma. He listed nine species, all Recent, with the descriptions of two new varieties.

Jack and Etheridge Jnr. (1893) again listed these forms together with many associated Lower Cretaceous megafossils from the locality.

Howchin (1884) identified 25 species of foraminifera from bores at Hergott Township (now Marree) and its vicinity in South Australia and later (1895) he described and figured two new species, *Haplophragmium australis* and *Patellina jonesi* from the material. In 1893, he listed 56 species from two bores Nos. 1 and 2 Hergott Township from Tarkaninna, 30 miles north-east of Hergott, from Mirrabuckinna, 43 miles south of Hergott and from William Creek, 125 miles north-west of Hergott, from Wilcannia, New South Wales and from surface material at Wallumbilla, Queensland. All species listed other than the two mentioned above were referred to species described chiefly from Recent forms. The writer has examined many of these specimens which are housed in the South Australian Museum, Adelaide and discovered that many of the species, although referred to Recent forms, were typical of the assemblage which appears in the majority of bores in the Great Artesian Basin and included species described by Crespin (1944) and others about to be described in this paper. Crespin (1944) described and figured eight new species of foraminifera from bores in northern New South Wales and preliminary notes on the microfaunas of some bores and outcrops in the Great Artesian Basin were given in a mimeographed departmental report (1945).

DESCRIPTION OF SPECIES

Genus **Pelosina** Brady, 1879

Pelosina lagenoides sp. nov.

Plate 5, figure 1

Test free, invariably crushed to an elongate flask shape; wall siliceous, composed of very fine quartz grains, smooth; aperture, simple, terminal at end of a short neck. Length, 0.47 mm.; greatest width 0.21 mm.

Holotype (Comm. Pal. Coll. No. 889) from Kopperammanna Bore, 460 miles north-east of Adelaide and

north-east of Lake Eyre, South Australia at the depth of 1,907 feet.

This species bears some resemblance to *P. elongata* a Recent form described by Wiesner from the Antarctic, but *P. lagenoides* is much smaller. The genus is comparatively rare in the Lower Cretaceous.

Genus **Ammodiscus** Reuss, 1861
Ammodiscus rotalarius Loeblich and Tappan

Plate 5, figure 2

Ammodiscus rotalarius LOEBLICH and TAPPAN, 1949, p. 247, pl. 46, fig. 1.

"Test free, discoidal, consisting of a proloculum and a long, tubular, individual second chamber which increases in size regularly, periphery rounded, sides flat; spiral suture not depressed, somewhat obscure until specimens are dampened; wall finely arenaceous with considerable cement, aperture at the open end of the tubular chamber." Greatest diameter 0.78 mm.; greatest thickness 0.12 mm.

Hypotype (Comm. Pal. Coll. No. 890) from Stevenson's Bore, about 650 miles north-north-west of Adelaide, South Australia, at the depth of 824 feet.

There seems little doubt that the South Australian species is identical with *A. rotalarius* described by Loeblich and Tappan from the Lower Cretaceous (Walnut Formation) of Texas, U. S. A. It varies only in size, the Australian form being slightly larger.

Genus **Haplophragmoides** Cushman, 1910
Haplophragmoides chapmani Crespin

Plate 5, figure 3

Haplophragmoides chapmani CRESPIN, 1944, p. 19, pl. 1, figs. 2*a, b,* 3.

The holotype of *H. chapmani* is refigured here. The species is a common one in many assemblages both from bores and outcrops. It occurs in bores in New South Wales, in bores and outcrops in Queensland and in bores in South Australia. Diameter of test, 0.72 mm.; thickness of test, 0.29 mm.

Holotype (Comm. Pal. Coll. No. 252) from bore on D. Murray's property, "Goolgumbe," 30 miles north-east of Bourke, Northern New South Wales, at the depth of 277 feet.

Haplophragmoides dickinsoni Crespin sp. nov.

Plate 5, figure 6

Test small, planispiral, closely coiled, periphery broad and round; chambers distinct, completely involute, six in the last whorl; sutures distinct, straight, slightly depressed; wall smooth, composed of fine arenaceous material with much cement; aperture, low arch at base of apertural face of last chamber; brownish in colour. Greatest diameter, 0.55 mm.; greatest thickness, 0.21 mm.

Holotype (Comm. Pal. Coll. No. 891) from Bore at Oodnadatta, 550 miles, north-north-west of Adelaide, South Australia at the depth of 965-1,000 feet.

H. dickinsoni shows some resemblance to *K. kirki* Wickenden in its robust shape. It differs, however, from that species in its larger number of chambers and in its less depressed sutures. It has the rounded profile of *H. globosa* Lozo but it has less chambers than that species and is completely involute. The species is named after Mr. S. B. Dickinson, Director of Mines, Adelaide, South Australia.

Genus **Ammobaculites** Cushman, 1910
Ammobaculites australe (Howchin)

Plate 5, figure 7

Haplophragmium sp., HOWCHIN, 1884, p. 86.
Haplophragmium australis HOWCHIN, Ms. 1894, p. 364. 1893, p. 198, pl. 10, figs. 1, 2.
Ammobaculites australe CRESPIN, 1944, p. 18, pl. 1, fig. 1; 1945, p. 3.

Test compressed, early portion coiled, later uncoiled with only two linear chambers, the last chamber being strongly inflated and terminating in a simple aperture; wall coarsely arenaceous. Length of test 1.8 mm.; diameter of coiled chambers 1.0 mm.

Hypotype (Comm. Pal. Coll. No. 892) from cliff section, Bungeworgorai Creek, 5 miles west of Roma, Queensland, and south of the Great Western Railway Line.

The specimen figured here resembles the type described by Howchin from No. 1 Bore, Hergott Township (now Marree) 360 miles north of Adelaide, South Australia between the depths of 100 feet and 200 feet. *A. australe* is not a common form but its distribution is widespread throughout the Great Artesian Basin.

Ammobaculites fisheri Crespin sp. nov.

Plate 5, figures 4, 5

Test free, small, elongate, early portion compressed, closely coiled and slightly compressed; later portion uniserial, nearly round in section; chambers numerous, five in coiled portion and six in uniserial part, very gradually increasing in size and slightly inflated; first uniserial chamber smaller than the succeeding ones, all slightly inflated; sutures distinct and depressed throughout; wall coarsely arenaceous; aperture terminal, elongate. Length of holotype, 0.81 mm.; greatest diameter of coiled portion, 0.17 mm.; length of uniserial portion 0.67 mm. Length of paratype 0.72 mm.; greatest diameter of coiled portion 0.15 mm.; length of uniserial portion, 0.6 mm.

Holotype (Comm. Pal. Coll. No. 893) from Bore No. 3752 on G. M. Taylor's property, 3 miles south of Ford's Bridge, and about 40 miles north-west of Bourke, northern New South Wales at 404 feet. Para-

type (Comm. Pal. Coll. No. 894) from outcrop at Flinders River, near Hughenden, Central Queensland.

This long, slender species of *Ammobaculites* shows little resemblance to any described forms from the Lower Cretaceous. However, *A. inconspicua,* described by Cushman and Waters from the Permian of Brown County, Texas, with its elongate shape and small, inflated, uniserial chambers, is very similar. *A. fisheri* has been recorded from various localities in Queensland as well as from bores in northen New South Wales. The species is named in honour of Dr. N. H. Fisher, Chief Geologist, Bureau of Mineral Resources, Geology and Geophysics, Canberra.

Ammobaculites minimus Crespin sp. nov.

Plate 5, figure 8

Test free, small, flattened, early chambers closely coiled then becoming uniserial; test consists of seven chambers, four in coiled portion and three in uniserial portion; sutures depressed and distinct; wall finely arenaceous, surface smoothly finished; aperture terminal, elongate. Length of test 0.48 mm.; thickness 0.09 mm.; greatest width of coiled portion 0.19 mm.

Holotype (Comm. Pal. Coll. No. 895) from Kopperamanna Bore, 460 miles north-east of Adelaide, South Australia and northeast of Lake Eyre at the depth of 1,907 feet.

A. minimus shows little resemblance to any described species of *Ammobaculites.* The species has been found chiefly at localities in Queensland but is also recorded from the Anacoora Bore, in southern Northern Territory.

Genus **Spiroplectammina** Cushman, 1927

Spiroplectammina cushmani Crespin

Plate 5, figure 9

Spiroplectammina cushmani Crespin, 1944, p. 19, pl. 1, fig. 7.

A megalospheric specimen is figured here and it is very similar to the type which came from the depth of 103 feet in a bore on D. Murray's property, "Goolgumble," 30 miles northeast of Bourke, northern New South Wales. Microspheric specimens were common in sandy shales in Bungil Creek and its tributaries, about 5 miles north of Roma, Queensland. *S. cushmani* has been found at many localities around Roma and in several bores in northern New South Wales. Length, 0.19 mm.

Hypotype (Comm. Pal. Coll. No. 896) from bore on D. Murray's property "Goolgumble," 30 miles north-east of Bourke, northern New South Wales at 277 feet.

Spiroplectammina edgelli Crespin sp. nov.

Plate 5, figure 10

Test small, elongate, compressed; early portion closely coiled, later portion biserial, the last two pairs of chambers rapidly increasing in size and width; periphery lobulate; sutures distinct in coiled portion but oblique and indistinct in biserial portion and marked at times only by depressions between chambers; wall coarsely arenaceous, composed of grains of clear quartz with greyish cement; aperture slit-like, at base of last chamber. Length of test 0.6 mm.; greatest thickness 0.09 mm.; greatest width of biserial portion, 0.3 mm.

Holotype (Comm. Pal. Coll. No. 897) from Kopperamanna Bore, 430 miles north-north-east of Adelaide and north-east of Lake Eyre, South Australia, at the depth of 2,110 feet.

This species has some resemblance to *S. scotti* Cushman and Alexander from the Lower Cretaceous of Texas. It differs from that species in its less compressed test and the rapidly increasing width of the last two pairs of chambers. *S. edgelli* is not a common form and has been recorded mainly from localities in Queensland. The species has been named after H. S. Edgell who prepared the excellent figures for this paper.

Genus **Ammobaculoides** Plummer, 1932

Ammobaculoides coonanaensis Crespin sp. nov.

Plate 5, figure 11

Test free, very small, flattened; early portion closely coiled, later biserial, then final chambers tending to become uniserial; four chambers in coil which increase in size, followed by two biserial chambers and a final uniserial one; sutures depressed, straight in coil, oblique in uniserial portion; wall finely arenaceous, smooth, aperture elongate. Length 0.24 mm.; greatest width 0.09 mm.

Holotype (Comm. Pal. Coll. No. 898) from Coonana Bore, South Australia, 370 miles north-north-east of Adelaide and 40 miles due east of Lake Callabonna, at the depth of 1,185-1,310 feet.

A. coonanaensis resembles slightly *A. phalus* described by Loeblich and Tappan from the Lower Cretaceous of Kansas. Both species are very small and have four to five chambers in the coiled portion and depressed sutures in the later portion of the test. The species is rather rare in the Lower Cretaceous deposits of the Great Artesian Basin.

Ammobaculoides pitmani Crespin sp. nov.

Plate 5, figure 12

Test free, small, flattened in early portion, becoming rounded in later portion; early portion coiled, later biserial and finally uniserial; periphery of coiled portion acute but gradually becoming rounded as in the direction of the uniserial chambers; eight chambers in test, four small ones in coiled portion, two larger ones in biserial portion and two larger ones in the uniserial part; uniserial chambers almost lobate; sutures in

coiled portion straight, fairly distinct; later ones distinct and depressed; wall arenaceous, smooth, polished; aperture terminal in last formed chamber. Length of test 0.5 mm.; greatest width 0.2 mm.; greatest thickness 0.18 mm.

Holotype (Comm. Pal. Coll. No. 899) from cliff section of Bungeworgarai Creek, 5 miles west of Roma, on the southern side of Great Western Railway Line, Queensland.

This compact species of *Ammobaculoides* seems to be quite distinct from any described species from the Lower Cretaceous. It has been found at various localities around Roma and in bores in Northern New South Wales. It is named after Mr. Derek Pitman of the Roma Blocks Oil Co. N. L.

Ammobaculoides romaensis Crespin sp. nov.
Plate 5, figures 13, 14

Test free, elongate, moderately large, early periphery rounded, later portion slightly flattened; early portion planispirally coiled and evolute, later biserial and finally becoming uniserial; chambers numerous, gradually increasing in size as added until uniserial portion, when they are fairly uniform; four chambers in last whorl of coiled portion, followed by ten biserial chambers and 5 uniserial oblong-shaped ones; sutures in coiled portion straight, fairly distinct particularly when test is dampened; later sutures distinct, depressed giving a slightly lobate outline; wall finely arenaceous with much siliceous cement; aperture small, depressed, on the last formed chamber; colour whitish; four chambers in uniserial portion of paratype followed by five in biserial portion and seven in uniserial portion. Length of holotype 1.15 mm.; greatest width 0.31 mm. Length of paratype 1.35 mm.; greatest width 0.3 mm.

Holotype (Comm. Pal. Coll. No. 900) from Bungeworgarai Creek, five miles west of Roma, Queensland, and below the old Mt. Abundance Homestead in blackish shale containing flint-like boulders with ammonites and mollusca. Paratype (Comm. Pal. Coll. No. 901) from low cliff section, Bungeworgarai Creek, 5 miles west of Roma, and 400 feet south of the Great Western Railway line in ochreous sandy marl.

The large size of this species seems to make it unique amongst the described species of *Ammobaculoides*. Both the holotype and paratype have been slightly deflated and it is difficult to obtain complete tests which have not suffered in this respect. *A. romaensis* is a common form in the Lower Cretaceous deposits around Roma, Queensland and it is found in many bores in the Great Artesian Basin. In the Peachawarrina Bore, 375 miles north-east of Adelaide, South Australia, the species was found in samples at the depths between 2,043 feet and 2,202 feet. In the section near the old Mt. Abundance Homestead, near Roma, it occurred in shales containing species of belemnites and ammonites characteristic of the Roma area.

Genus **Textularia** Defrance, 1824
Textularia anacooraensis Crespin sp. nov.
Plate 5, figure 15

Test small, elongate, narrow throughout; periphery rounded; chambers numerous, biserially arranged in nine pairs, increasing gradually in size; sutures distinct, depressed, oblique; wall finely arenaceous, smoothly finished; aperture apparently a low arch at base of last formed chamber. Length of test 0.6 mm.; greatest width 0.15 mm.; thickness 0.08 mm.

Holotype (Comm. Pal. Coll. No. 902) from Anacoora Bore, southern Northern Territory, 670 miles north-north-east of Adelaide, at the depth of 1,110-1,123 feet.

This small elongate species seems unique amongst Lower Cretaceous Textularidae. The majority of described species are much larger and much broader than *T. anacooraensis*.

Genus **Verneuilina** d'Orbigny, 1840
Verneuilina howchini Crespin sp. nov.
Plate 5, figure 16

Test triserial, elongate, tapering, from acute initial end to greatest width near apertural end; sharply triangular in traverse section; sides deeply concave; chambers fairly distinct, seven in number, sutures indistinct, curved; angles of chambers somewhat rounded; wall finely arenaceous, smoothly finished; aperture, a narrow opening on the inner margin of the last formed chamber. Length of test 0.8 mm.; width in upper third 0.38 mm.

Holotype (Comm. Pal. Coll. No. 903) from Anacoora Bore, southern Northern Territory, 670 miles north-north-west of Adelaide, South Australia at the depth of 710-720 feet.

This species resembles somewhat *V. limbata* Cushman. The periphery of the triserial angles is rather more rounded than in that species and the sides are more deeply concave. *V. howchini* has also been found in the Roma area and at Flinders River, Hughenden, Queensland. The species has been named in honour of the late Professor Walter Howchin, who was one of the earliest workers on the Lower Cretaceous foraminifera in Australia.

Genus **Bigenerina** d'Orbigny, 1826
Bigenerina loeblichae Crespin, sp. nov.
Plate 5, figures 17, 18

Holotype. Megalospheric form. Test moderately large, flatly ovate in section, some flattening due to compression; early portion biserial, later portion uniserial; periphery rounded; seven chambers in biserial

portion, gradually increasing in size; four chambers in uniserial portion gradually increasing in size until last chamber, which is almost rectangular in shape; sutures distinct, thick, oblique in biserial portion and straight and depressed in uniserial part; wall finely arenaceous, smooth; aperture, terminal, ovate in shape on top of last chamber. Length of test 0.88 mm.; greatest width in biserial portion, 0.2 mm.; greatest width in uniserial portion 0.26 mm.

Paratype. Microspheric form. Test large, with biserial portion tapering sharply; nine chambers in biserial portion, gradually increasing in size; seven in uniserial portion. Length of test 1.19 mm.; greatest width of biserial portion 0.18 mm.; greatest width of uniserial portion 0.26 mm.

Holotype (Comm. Pal. Coll. No. 904) from Marree Bore, South Australia, 360 miles north of Adelaide, from the depth of 70-110 feet. Paratype (Comm. Pal. Coll. No. 905) from cliff section Bungeworgarai Creek, Queensland, 5 miles west of Roma, on south side of the Great Western Railway Line.

This species shows some resemblance to *Bigenerina wintoni* Cushman and Alexander but the difference lies in the collapsed appearance of the biserial chambers. Variation of length of test and difference in shape of the biserial portion is a distinctive character in both the megalospheric and microspheric forms of *B. loeblichae*. The species is common in the Lower Cretaceous deposits around Roma and occurs in bores in northern South Australia and northern New South Wales. It is named after Mrs. Helen Loeblich who kindly checked all arenaceous species described in this paper during a recent visit by the writer to Washington, D. C.

Genus **Trochammina** Parker and Jones, 1859

Trochammina minuta Crespin sp. nov.

Plate 5, figures 19a, b

Test free, very small, compressed, trochoid; periphery lobate; eight chambers visible on dorsal surface, only five on the ventral side; chambers increase gradually in size as added; sutures rather indistinct but contracted at the margin to give lobate periphery; wall finely arenaceous; aperture small at base of apertural face of last formed chamber. Greatest diameter of test, 0.26 mm.; greatest thickness 0.09 mm.

Holotype (Comm. Pal. Coll. No. 906) from Wallumbilla Creek, Queensland, Wallumbilla Township, Queensland, 24 miles east of Roma.

This species is one of the smallest of the genus. Helen Loeblich suggested it may be similar to *T. depressa* Lozo but the test is rounder in shape, the chambers are narrower and the whorls are more evenly coiled than in that species.

Trochammina raggatti Crespin

Plate 6, figure 1

Trochammina raggatti Crespin, 1944, p. 20, pl. 1, figs. 4*a-c*, 5; 1945, p. 3.

The specimen figured here is slightly more depressed than the type. The species is widely distributed in bores in the Great Artesian Basin and is also common in outcrops around Roma, Queensland. Diameter, 0.66 mm.; thickness, 0.06 mm.

Hypotype (Comm. Pal. Coll. No. 907) from a bore on D. Murray's property "Goolgumble," 30 miles north-east of Bourke, northern New South Wales at the depth of 265-277 feet.

Genus **Robulus** Montfort, 1808

Robulus gunderbookaensis (Crespin)

Plate 6, figures 2a, b

Lenticulina gunderbookaensis Crespin, 1944, p. 21, pl. 1, figs. 9*a*, *b*.

Test smooth, translucent, compressed, closely coiled, evolute, almost circular; periphery slightly keeled; sutures distinct, curved, slightly depressed; aperture radiate, but not prominent, at apex of apertural face, with an indistinct robuline slit. Length of test 0.85 mm.; greatest width 0.7 mm.; thickness 0.25 mm.

Hypotype (Comm. Pal. Coll. No. 908) from Marree Bore, South Australia, 360 miles north of Adelaide, at the depth of 140 feet.

This species, though not common, is found in widely separated localities in the Great Artesian Basin. The holotype was taken from Bore No. 3785 on W. R. Johnston's property "Calooma," 4 miles south-east of Lila Springs and 30 miles north-north-west of Bourke, northern New South Wales.

Robulus warregoensis (Crespin)

Plate 6, figure 3

Lenticulina warregoensis Crespin, 1944, p. 21, pl. 1, figs. 8*a*, *b*.

Test medium size, elongate, nearly twice as long as broad, ovate, translucent, smooth, moderately flat in profile; periphery acute; peripheral outline evenly curved; chambers eleven, early ones involute, rapidly becoming evolute and increasing in size; sutures smooth, curved, especially in early portion where they are close together; aperture radiate with faint slit below and protruding. Length of test 0.86 mm.; greatest width 0.6 mm.; thickness 0.25 mm.

Hypotype (Comm. Pal. Coll. No. 909) from Marree Bore, South Australia, 360 miles north of Adelaide, at the depth of 120 feet.

This species is usually present when calcareous genera occur and many tests are well preserved. The holotype came from Bore No. 3843 on A. Holmes's prop-

erty near Ellaville, about 50 miles north-west of Bourke, northern New South Wales.

Genus **Lenticulina** Lamarck, 1804
Lenticulina australiensis Crespin sp. nov.
Plate 6, figure 4

Test small, planispiral, moderately flat, elongate, keeled; seven chambers gradually increasing in size; sutures distinct, smooth, sharply curved in early portion, becoming more gently curved; wall calcareous, smooth; aperture radiate, protruding at peripheral angle. Length of test 0.53 mm.; greatest width 0.35 mm.; greatest thickness 0.19 mm.; length of apertural face 0.26 mm.

Holotype (Comm. Pal. Coll. No. 910) from Marree Bore, South Australia, 360 miles north of Adelaide, at the depth of 190 feet.

Some described species from the Jurassic show some resemblance to *L. australiensis,* especially with regard to the projecting aperture, which is a strong feature of this form. However, none of them are identical with it.

Genus **Marginulina** d'Orbigny, 1826
Marginulina marreensis Crespin sp. nov.
Plate 6, figure 5

Test small, elongate, rather compressed transversely; coil at the base forming a bluntly rounded initial end, followed by three uncoiled chambers; uncoiled chambers gradually increasing in size until apertural chamber which is inflated and is equivalent in size to two chambers together; sutures distinct, oblique; wall smooth, polished; aperture radiate, terminal at end of slight neck. Length of test 0.6 mm.; width of last chamber 0.23 mm.

Holotype (Comm. Pal. Coll. No. 911) from Marree Bore, South Australia, 360 miles north of Adelaide, at the depth of 190 feet.

This species closely resembles *M. modesta* Reuss which he described from the Upper Cretaceous of Germany. The last chamber is more bulbous in that species than in *M. marreensis* and the uncoiled chambers number six with only three in the South Australian species.

Genus **Marginulinopsis** Silvestri, 1904
Marginulinopsis australis Crespin sp. nov.
Plate 6, figures 6, 7

Holotype. Test small, elongate, early portion coiled, rapidly becoming uncoiled, subcylindrical; dorsal and ventral margins straight with uncoiled portion slightly flattened; five chambers in coiled portion, four in uncoiled portion; chambers in uncoiled portion distinct, the first three being almost uniform in size; apertural chamber large, inflated; sutures indistinct in coiled portion, distinct and slightly oblique in uncoiled portion; wall smooth, calcareous; aperture radiate, protuberant at the outer peripheral angle. Length of test 0.73 mm.; width 0.23 mm.

Paratype. Dorsal margin slightly concave, ventral margin slightly convex with the third uncoiled chamber abnormally inflated; five chambers in coiled portion, five in uncoiled portion, two of those chambers being rather flattened. Length of test 1.3 mm.; width 0.33 mm.

Holotype (Comm. Pal. Coll. No. 912) from Marree Bore, South Australia, 360 miles north of Adelaide, at the depth of 190 feet. Paratype (Comm. Pal. Coll. No. 913) from the same bore as holotype but from the depth of 180 feet.

This form shows some resemblance to a figure of *Marginulina texana* Cushman 1946 (pl. 21, fig. 29) from the Upper Cretaceous of Texas, especially in the straightness of the uncoiled part of the test. However, in that figure, the coiled portion is not so distinct and the uncoiled chambers are not uniform in size. *M. taylorana* shows a more distinct coil but less chambers are present than in *M. australis.* The species is not common and the only other record is from the Longreach Oil Bore, central Queensland at the depth of 1,909 feet.

Marginulinopsis subcretaceus (Crespin)
Plate 6, figures 10, 11

Marginulina subcretacea Crespin, 1944, p. 21, pl. 1, fig. 10.

Test elongate, earliest portion slightly coiled, rapidly uncoiling; seven chambers in adult stage; early portion slightly compressed, later chambers becoming inflated, the last chamber which has lost outer wall being almost circular in section; sutures distinct and slightly oblique; wall of initial chambers smooth but later ones ornamented with longitudinal costae, twenty on the first four adult chambers then bifurcating on the fifth chamber and continuing as fine and more numerous costae until last chamber; aperture radiate on outer margin of last chamber. Length of test 2.9 mm.

A well preserved, juvenile specimen is figured as a hypotype. Early portion bulbous; four uncoiled chambers, with the last chamber inflated; wall calcareous, covered with twenty fine costae, which commence on the coiled portion but gradually disappear near the apertural end. Length of holotype 2.90 mm. Length of hypotype 0.76 mm.; width 0.31 mm.

Holotype (Comm. Pal. Coll. No. 258) from Bore No. 3843, on A. Holmes's property near Ellaville, about 50 miles north-west of Bourke, northern New South Wales at the depth of 450 feet. Hypotype (Comm. Pal. Coll. No. 914) from No. 2 Bore, Neargo, 45 miles south of Mungindi, northern New South Wales at the depth of 355 feet.

Genus **Pseudoglandulina** Cushman, 1929

Pseudoglandulina regularis Crespin sp. nov.

Plate 6, figure 8

Test small, straight, rounded in cross section; consisting of three chambers, third chamber comprising almost one half of entire length; first two chambers about equal in size; sutures straight, distinct, depressed; wall calcareous, smooth, polished; aperture terminal, radiate. Length of test 0.37 mm.; width 0.16 mm.; length of last chamber 0.17 mm.

Holotype (Comm. Pal. Coll. No. 915) from Marree Bore, South Australia, 360 miles north of Adelaide, at the depth of 150 feet.

This form with its regularly shaped chambers bears some resemblance to *P. mutabilis* (Reuss) but in that species the chambers increase rapidly in size. *P. regularis* has also been recorded from the Longreach Oil Bore, central Queensland at the depth of 1,901 feet.

Genus **Lagena** Walker and Jacob, 1798

Lagena apiculata Reuss var. **phialaeformis** Crespin nov.

Plate 6, figure 9

Test small phial-shaped, broad at the base and gradually tapering towards aperture; base of test gently angular with a short spine centrally placed; aperture radiate. Length of test 0.5 mm.; width at base 0.16 mm.; width immediately below aperture 0.07 mm.

Holotype of variety (Comm. Pal. Coll. No. 916) from Marree Bore, South Australia, 360 miles north of Adelaide at the depth of 160 feet.

This new varietal form of *L. apiculata* resembles somewhat *L. apiculata* var. *elliptica* Reuss which was described from the Upper Gault of Germany. The South Australian form, however, tapers from the base to the aperture while the other variety is regularly elliptical in shape. The genus *Lagena* is not common in the Lower Cretaceous deposits of the Great Artesian Basin.

Genus **Valvulineria** Cushman, 1926

Valvulineria infracretacea Crespin nom. nov.

Plate 6, figures 12a, b; 13a, b

Planulina cretacea Crespin, 1944, p. 22, pl., figs. 11*a*, *b*; 12*a*, *b*.

Trochammina parvula Crespin, 1944, p. 20, pl. 1, figs. 6*a*, *b*.

Holotype. Test small trochoid, dorsal face gently convex, ventral face concave with a small umbilicus; periphery rounded; six chambers in final whorl; chambers rapidly increasing in size; sutures depressed, indistinct curved; last chamber on ventral face large and slightly inflated with a fairly strong lobe partially covering umbilical area; wall smooth, calcareous, finely perforate; purplish grey in colour. Diameter of holotype 0.40 mm.

Hypotype. Test small trochoid, dorsal face gently convex, ventral face concave with a small umbilicus; five chambers in last whorl on dorsal side and six on ventral side; chambers irregular in size with the last two rather large. Diameter 0.3 mm.; thickness 0.14 mm.

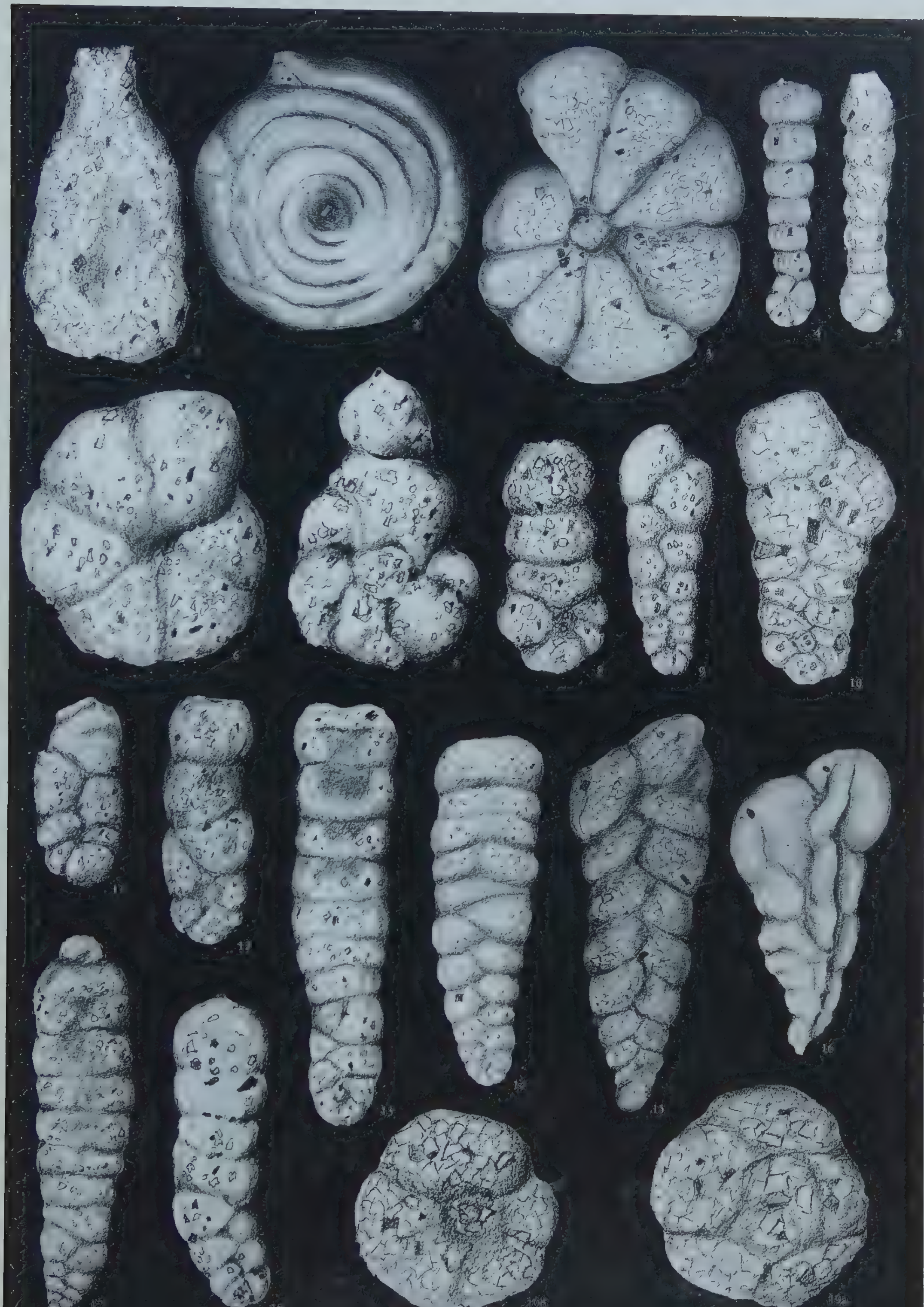
Holotype (Comm. Pal. Coll. No. 259) from Bore No. 3785 on W. R. Johnston's property "Calooma" 4 miles south-east of Lila Springs and 30 miles north-north-west of Bourke, northern New South Wales, at the depth of 400 feet.

Hypotype (Comm. Pal. Coll. No. 917) from Bore No. 3864 on P. A. McGirr's property "Lauradale" about 12 miles north-north-east of Bourke, northern New South Wales at the depth of 850 feet.

This form was originally described by Crespin under the name of *"Planulina cretacea."* Better preserved specimens show that the genus should be *"Valvulinera."* With this change of genus it is necessary to

EXPLANATION OF PLATE 5

Illustrations drawn by H. S. Edgell



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Crespin: Lower Cretaceous Foraminifera from Australia

Drawn by H. S. Edgell

Crespin: Lower Cretaceous Foraminifera from Australia

change the specific name "*cretacea*" as *Valvulineria cretacea* has been pre-occupied by Carsey, 1926. The proposed new name is *Valvulineria infracretacea*. It must also be noted that the species described by Crespin (1944) as *Trochammina parvula* must be placed in the synonymy of *V. infracretacea*. The peculiar mode of preservation of the tests and the variability in shape has led to these errors. The species is common in certain bores in northern New South Wales.

Genus **Epistomina** Terquem, 1883

Epistomina australiensis Crespin sp. nov.

Plate 6, figures 14a, b

Test small biconvex; periphery acute, slightly keeled; eleven chambers visible on dorsal surface, six on last formed whorl, flat, gradually increasing in size, uniform in shape until last chamber which is large; sutures gently curved on both dorsal and ventral sides, fairly thick in early whorls, and lightish in colour; wall very finely punctate; aperture just below periphery on ventral side and along ventral margin of last chamber; narrow slits on ventral side near peripheral margin. Diameter of test 0.21 mm.; thickness 0.1 mm.

Holotype (Comm. Pal. Coll. No. 918) from Mirra Mitta Bore, South Australia, 490 miles north of Adelaide at the depth of 1,830-1,980 feet.

This species resembles the figure given by Cushman (1941) and others, of *Epistomina caracolla* (Roemer) but it is quite different from the type in which the sutures are straight on both ventral and dorsal surfaces. The ventral surface is also strongly convex with a strong central boss.

Genus **Globigerina** d'Orbigny, 1826

Globigerina cretacea d'Orbigny

Plate 6, figures 15a, b, c

Globigerina cretacea D'ORBIGNY, 1840, p. 34, pl. 3, figs. 12-14.

Globigerina cretacea CHAPMAN, 1917, p. 37, pl. 9, fig. 102; pl. 12, fig. 124.

Globigerina cretacea TAPPAN, 1943, p. 152, pl. 82, figs. 16*a*-17.

This small species occurs commonly in some of the bores in the Great Artesian Basin. It was very common at the depth of 4,906 feet in the Patchawarra Bore, 540 miles north-north-east of Adelaide, South Australia, from which the figured specimen was taken. Diameter of test, 0.2 mm.

Hypotype (Comm. Pal. Coll. No. 919) from Patchawarra Bore, South Australia, 540 miles north of Adelaide at the depth of 4,906 feet.

Globigerina planispira Tappan

Plate 6, figure 16

Globigerina planispira TAPPAN, 1940, p. 112, pl. 19, figs. 12*a-c*; 1943, p. 153, pl. 83, fig. 3.

"Test tiny, in a low trochoid spire of two volutions; chambers six to seven in a whorl, increasing rapidly in size, bulbous; sutures distinct and constricted; wall calcareous, surface smooth; aperture opening into a deep umbilical excavation." Diameter of hypotype 0.2 mm.; thickness through centre 0.06 mm.

Hypotype (Comm. Pal. Coll. No. 920) from Koppermanna Bore, South Australia, 430 miles north of Adelaide, at the depth of 1,907 feet.

This minute species of *Globigerina* is identical with that described by Tappan from the upper part of the Grayson Bluff, Denton County, Texas. It is not very common in the Lower Cretaceous deposits of the Great Artesian Basin, and its only other record is at a locality 34 miles from Barcaldine on the Barcaldine-Aramac Road, central Queensland.

EXPLANATION OF PLATE 6

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Illustrations drawn by H. S. Edgell

Genus **Anomalina** d'Orbigny, 1826

Anomalina mawsoni Crespin sp. nov.

Plate 6, figures 17a, b

Anomalina rubiginosa CRESPIN, (non Cushman), 1944, p. 22.

Test small, nautiloid, closely coiled; dorsal surface nearly flat, ventral surface concave; periphery broadly rounded, lobate; only seven chambers visible in last formed coil, gradually increasing in size, last chamber on ventral surface extending over imbilical area; sutures rather indistinct in early chambers, distinct in later ones; wall smooth; aperture an arched slit at the base of the last chamber. Diameter 0.36 mm.; thickness 0.15 mm.

Holotype (Comm. Pal. Coll. No. 921) from Marree Bore, South Australia, 360 miles north of Adelaide, at the depth of 120 feet.

This small species was originally determined by Crespin (1944) as *A. rubiginosa* Cushman which is common in the Upper Cretaceous. However, many specimens have been available for study since 1944 and it has been found that it differs in certain respects from that species. The wall of *A. mawsoni* is smooth rather than coarsely perforated as in *A. rubiginosa* and the form generally is more regular in shape. The species is named after Sir Douglas Mawson, Professor of Geology, Adelaide University.

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RECENT LITERATURE ON THE FORAMINIFERA

Below are given some of the more recent works on the Foraminifera that have come to hand.

AKERS, W. H. General ecology of the foraminiferal genus **Eponidella** with description of a Recent species. —Journ. Pal., vol. 26, No. 4, July 1952, pp. 645-649, text figs. 1, 2.—**E. gardenislandensis** n. sp., from shallow, brackish-water, extends the range of the genus into the Recent.

ALBERS, JÜRGEN. Taxonomie und Entwicklung einiger Arten von **Vaginulina** d'Orb. aus dem Barrême bei Hannover (Foram.).—Mitteil. Geol. Staatsinstitut Hamburg, heft 21, April 1952, pp. 75-112, pls. 4, 5, text figs. 1-30.—Six species, one new, and one new subspecies are described and illustrated. The development of the species in a well section is statistically studied.

ANDERSEN, HAROLD V. **Buccella**, a new genus of the rotalid Foraminifera.—Journ. Washington Acad. Sci., vol. 42, No. 5, May 1952, pp. 143-151, figs. 1-13.—Eight species, three new, are illustrated and described in detail, and placed in the new genus **Buccella** (genotype **Eponides hannai** Phleger and Parker).

ARNOLD, ZACH M. Structure and paleontological significance of the oral apparatus of the foraminiferoid **Gromia oviformis** Dujardin.—Journ. Pal., vol. 26, No. 5, Sept. 1952, pp. 829-831, text fig. 1.

BARNARD, TOM. Foraminifera from the Upper Lias of Byfield, Northamptonshire.—Quart. Journ. Geol. Soc. London, vol. 106, pt. 1, Dec. 28, 1950, pp. 1-36, pls. 1-3, text figs. 1-17.—Forty-two species and varieties, 4 new, are described and illustrated.

BARTENSTEIN, HELMUT, and BRAND, ERICH. Mikropaläontologische Untersuchungen zur Stratigraphie des nordwestdeutschen Valendis.—Abhandl. Senckenberg. Naturforsch. Gesellschaft, No. 485, 1951, pp. 239-336, pls. 1-25.—Over two hundred species and subspecies, 61 new, are described and illustrated and their stratigraphic distribution in wells is shown. Excellent photographs show foraminifera and ostracode associations at various depths in the wells.

BERMUDEZ, P. J., and KEY, C. E. Tres generos nuevos de Foraminiferos de las familias Reophacidae y Valvulinidae.—Mem. Soc. Ciencias Nat. La Salle, vol. 12, No. 31, 1952, pp. 71-77, text figs. 1-14.—**Ginesina** n. gen. (genoholotype **G. delicatula** n. sp.), **Dusenburyina** n. gen. (genotype **Clavulina procera** Goës), and **Cylindroclavulina** n. gen. (genotype **Clavulina bradyi** Cushman, 1911).

BOLIN, EDWARD J. Microfossils of the Niobrara formation of southeastern South Dakota.—South Dakota Geol. Survey Rept. of Investigations No. 70, April 1952, pp. 1-74 (mimeographed), pls. 1-5, text fig. 1 (map and sections), table 1.—Fifty-nine species of Foraminifera are recorded and illustrated. Four faunal zones are recognized.

BOLLI, HANS. Note on the Cretaceous-Tertiary boundary in Trinidad, B.W.I.—Journ. Pal., vol. 26, No. 4, July 1952, pp. 669-675.—The Lizard Springs formation is considered Paleocene.

BRONNIMANN, P. Globigerinidae from the Upper Cretaceous (Cenomanian-Maestrichtian) of Trinidad, B.W.I. —Bull. Amer. Pal., vol. 34, No. 140, June 9, 1952, pp. 1-70, pls. 1-4, text figs. 1-30.—Six species and 15 subspecies are described and illustrated, all but 4 new. Four genera, 2 new, and 3 subgenera, all new, are concerned: **Rugoglobigerina** n. gen. (generotype **Globigerina rugosa** Plummer) with two new subgenera, **Rugoglobigerina** and **Plummerella; Hastigerinoides** n. subgenus of **Hastigerinella;** and **Trinitella** n. gen. (generotype **T. scotti** n. sp.). Phyllogenetic trends are suggested and a table shows stratigraphic ranges.

Die Mundöffnungen bei **Asterigerina carinata** d'Orbigny 1839.—Eclogae Geol. Helvetiae, vol. 44, No. 2, 1951 (June 1952), pp. 469-474, text figs. 1-3.—Study of the structure of the test.

Remarks on the embryonic chambers of Upper Eocene Asterocyclinidae of Trinidad, B.W.I.—L. c., pp. 474-486, text figs. 1-10.—Three species are studied.

BUTCHER, W. S. Bottom sediments and Foraminifera from Labrador, **Blue Dolphin** 1951.—Woods Hole Oceanographic Instit., Ref. No. 52-20, March 1952, 13 pp. (mimeographed), 7 text figs.—Thirty-two species are recorded quantitatively from 16 samples from Nain Bay and Hamilton Inlet.

CHURCH, CLIFFORD C. A new species of Foraminifera of the genus **Discorbis** dredged off the coast of California.—Proc. Calif. Acad. Sci., 4th ser., vol. 27, No. 11, July 11, 1952, pp. 375, 376, pl. 20.

COLE, W. STORRS, and GRAVELL, DONALD W. Middle Eocene Foraminifera from Peñon Seep, Matanzas Province, Cuba.—Journ. Pal., vol. 26, No. 5, Sept. 1952, pp. 708-727, pls. 90-103.—Nineteen species, 6 new, belonging in 11 genera, one new: **Penoperculoides** (genotype **P. cubensis** n. sp.) placed in the family Amphisteginidae. The genus **Gunteria** is transferred to the family Cymbaloporidae.

COLOM, G., and GAMUNDI, J. Sobre la extensión e importancia de las "Moronitas" a lo largo de las formaciones aquitano-burdigalienses del estrecho nortbético. —Instit. "Lucas Mallada" Invest. Geol., Estudios Geologicos No. 14, 1951, pp. 331-385, pls. 25-36, text figs. 1-8, distribution tables.—A foraminiferal fauna associated with the diatom beds is illustrated and the stratigraphic distribution of species represented graphically.

CONKIN, JAMES. Extended studies on fossils from the Solomon Islands.—Annals Kentucky Nat. Hist., vol. 1, Art. 7, Feb. 1, 1952, pp. 49-55, pls. 2, 3.—An **Amphistegina** is found in Quaternary sediments.

COOKE, C. WYTHE and MacNEIL, F. STEARNS. Tertiary Stratigraphy of South Carolina.—U. S. Geol. Survey Prof. Paper 243-B, 1952, pp. 19-29, text fig. 2 (correlation chart).—Includes lists of Foraminifera.

CROUCH, ROBERT W. Significance of Temperature on Foraminifera from deep basins off southern California coast.—Bull. Amer. Assoc. Petr. Geol., vol. 36, No. 5, May 1952, pp. 807-843, pls. 1-7, text figs. 1-5, check list.—Four foraminiferal biozones based on temperature are recognized. About 100 species, most of them illustrated, are plotted as to distribution and abundance.

CUVILLIER, J. (with the collaboration of V. Sacal) Corrélations stratigraphiques par microfaciès en Aquitaine Occidentale.—Leiden, 1951, 23 pp., 90 pls.—Photographs of thin sections of Devonian to Miocene rocks.

DACI, ATIFE. Etude paléontologique du Nummulitique entre Küçükçekmece et Catalca, I and II.—Revue de la Faculté des Sciences de l'Université d'Istanbul, ser. B, vol. 16, fasc. 2, 1951, pp. 89-112; fasc. 3, 1951, pp. 207-246, pls. 1-5.—Numerous species, mostly num-

mulites, are described and illustrated, and other Foraminifera are listed.

DAM, A. TEN. On **Asterigerina güriehi** (Franke).—Journ. Pal., vol. 26, No. 4, July 1952, pp. 676, 677.—Improbability of recognition of trimorphism in fossil forms.

DROOGER, C. W. Study of American Miogypsinidae.—Thesis Univ. Utrecht, 1952, pp. 1-80, pls. 1-3, text figs. 1-18, tables 1, 2.—An important monographic study. Fourteen species are recognized, 4 new. Tentative phyllogenetic lines are suggested, using Tan's principle of nepionic acceleration. A new subgenus, **Miogypsinita** (type species **Miogypsina mexicana** Nuttall 1933), is proposed.

GANSS, O., and HILTERMANN, H. Zum Problem des Karpatenflysches (Bukowiec).—Zeitschrift Deutschen Geol. Gesellschaft, vol. 102, Oct. 31, 1951, pp. 272-286, pls. 7, 8, text figs. 1-3.—A few Foraminifera are listed and illustrated.

GLACON, G., MAGNÉ, JEAN, and MURAOUR, PIERRE. **Bolivina algeriana**, un nouveau Foraminifère du Miocène d'Algérie.—C.R.S. Soc. Géol. France, Feb. 4, 1952, No. 3, pp. 41-43, text figs. 1-9.

GRIMSDALE, T. F. Cretaceous and Tertiary Foraminifera from the middle East.—Bull. British Mus. (Nat. Hist.), Geol., vol. 1, No. 8, May 1952, pp. 223-247, pls. 20-25.—Fifteen species and varieties, 7 new, are described and illustrated from Oligocene to Senonian beds of Iraq.

HEGEDÜS, GY. Daten zur geologischen Kenntnis des Pilis-Gebirges.—Ann. Rept. Hungarian Geol. Instit. of the years 1945-47, 1951, pp. 173-190, 1 table, 2 text figs., 1 map.—Occurrence of Foraminifera is shown in a table.

HILTERMANN, HEINRICH. **Astrorhiza cretacea** Franke 1928 als Scheinfossil und ähnliche Wurzelröhrchen (Rhizosolenien).—Geol. Jahrb., vol. 66, May 1952, pp. 421-424, text figs. 1, 2.—Possibility of origin as root tubules.

Stratigraphische Fragen des Campan und Maastricht unter besonderer Berücksichtigung der Mikropaläontologie.—Geol. Jahrb., vol. 67, July 1952, pp. 47-66, text figs. 1-5, table 1.—Vertical ranges of selected species of Foraminifera are represented graphically for several locations. Three new species of **Neoflabellina** are described.

HOFKER, J. On Foraminifera from the Dutch Cretaceous.—Natuurhist. Genootschap Limburg, reeks 4, Aug. 15, 1951, pp. 1-40, text figs. 1-47.—Twelve genera and family groups, one new, and 20 species, 3 new, are described and illustrated in minute detail. Genus **Pullenoides** n. gen. (genotype **P. senoniensis** n. sp.). Reference is made to the Visser monograph on the Maestrichtian.

Zur fassung der Foraminiferengattung **Bolivinoides** Cushman 1927.—Geol. Jahrb., vol. 66, Jan. 1952, pp. 377-382, text figs. 1-6.

Zur Methode der Bearbeitung fossiler und rezenter Foraminiferen.—L. c., pp. 285-287.

Regeneration bei einer **Neoflabellina**.—L. c., pp. 289, 290, text fig. 1.—An abnormal specimen.

The Jurassic genus **Reinholdella** Brotzen (1948) (Foram.).—Paläont. Zeitschr., vol. 26, No. 1/2, Aug. 1952, pp. 15-29, text figs. 1-17.—Six species, 4 new, are described and illustrated, with notes on phyllogenetic relationships.

ILAVSKY, JAN, and CERVENOVA, ZELMIRA. Geologicke Studia na Zapadnom Svahu Vel'kej Fatry.—Geologicke Prace, Sosit 30, 1952, 61 pp., 18 pls.—A few genera of Foraminifera are illustrated from rocks of Jurassic to Paleocene age.

ITZHAKI, JEHOSHUA. Séries de variabilité de certaines espèces de Foraminifères sénoniens de la région de Bayonne, d'après les dimensions des tests et leur corrélation avec les strates.—C.R.S. Soc. Géol. France, May 19, 1952, No. 10, pp. 186, 187, 2 graphs.—**Globotruncana arca** increases in size in stratigraphically higher beds and **Gümbelina elegans** decreases.

Séries de variabilité de **Pseudotextularia varians** (Rzehak) d'après la forme du test et ses tendances évolutives.—L. c., pp. 187-189, 11 text figs.

KAYE, CLIFFORD A. Foraminifera in glacial till from northeastern Montana.—Bull. Geol. Soc. Amer., vol. 63, No. 8, Aug. 1952, p. 881.—Cretaceous forms probably from an outcrop 130 miles to the northeast in Canada.

LeROY, L. W. **Orbulina universa** d'Orbigny in Central Sumatra.—Journ. Pal., vol. 26, No. 4, July 1952, pp. 576-584, text figs. 1-4.—The lower limit of **O. universa** is accurately defined. The associated fauna, 67 species, is recorded and plotted on a stratigraphic chart. Notes regarding world-wide distribution of **Orbulina** are included.

LOEBLICH, ALFRED R. JR. **Ammopemphix**, new name for the Recent foraminiferal genus **Urnula** Wiesner.—Journ. Washington Acad. Sci., vol. 42, No. 3, March 15, 1952, p. 82.

New Recent foraminiferal genera from the tropical Pacific.—L. c., No. 6, June 15, 1952, pp. 189-193, figs. 1-5.—**Tawitawia** n. gen. (genotype **Textularia immensa** Cushman 1921) and **Paumotua** n. gen. (genotype **Eponides terebra** Cushman 1933).

LOEBLICH, ALFRED R. JR., and TAPPAN, HELEN. **Cribrotextularia**, a new foraminiferal genus from the Eocene of Florida.—L. c., No. 3, March 15, 1952, pp. 79-81, figs. 1-5.—**Cribrotextularia** n. gen. (genotype **Textularia coryensis** Cole).

Adercotryma, a new Recent foraminiferal genus from the Arctic.—L. c., No. 5, May 15, 1952, pp. 141, 142, figs. 1-4.—**Adercotryma** n. gen. (genotype **Lituola glomerata** Brady 1878).

Poritextularia, a new Recent foraminiferal genus.—L. c., No. 8, Aug. 15, 1952, pp. 264-266, figs. 1-3.—**Poritextularia** n. gen. (genotype **P. mexicana** n. sp.).

Morphology of the test in the foraminiferal genus **Tristix** Macfadyen.—L. c., No. 11, Nov. 1952, pp. 356-361, figs. 1-9.—The generic description of **Tristix** is revised, including **Quadratina** as a junior synonym; and a new species is described. A discussion of generic relationships and significance of internal tubes is included.

McLEAN, JAMES D. JR. New and interesting species of Foraminifera from the Vincentown formation. Part I. New Species.—Notulae Naturae, No. 242, April 16, 1952, pp. 1-13, pls. 1-3.—Fourteen species and one variety, all new.

MAJZON, LASZLO. Foraminifera investigations in the deep-boring laboratory.—Ann. Rept. Hungarian Geol. Instit. of the years 1945-47, 1951, pp. 329-337, 4 tables.—Foraminifera are listed from Chattian and Rupelian beds in two deep borings.

Recent data to the geology of the territory between Szilvasvarad and Csernely.—L. c., pp. 99-109, 1 table.—Foraminifera are listed from beds of Chattian to Sarmatian age.

Stratigraphy of the environs of Parad and Fedemes.—

L. c., pp. 135-149, 2 tables, 1 map.—Two tables show the distribution of the Foraminifera in the two areas.

MORIKAWA, ROKURO. **Nagatoella fujimotoi**, n. sp., and a new studying method for fusulinids.—Trans. Proc. Pal. Soc. Japan, n. ser., No. 3, Sept. 1951, pp. 81-84, pl. 8.—Method of etching in acetic acid.

NAPOLI ALLIATA, E. di. Considerazioni sulle microfaune del Miocene superiore italiano.—Riv. Ital. Pal., vol. 57, No. 4, 1951, pp. 91-122, pls. 4-6.—Foraminifera are listed and figured from some faunas transitional between marine and brackish conditions.

PARKER, FRANCES L. Foraminifera species off Portsmouth, New Hampshire.—Bull. Mus. Comp. Zoöl., vol. 106, No. 9, April 1952, pp. 391-423, pls. 1-6.—Seventy-four species and varieties, 6 new, are recorded and illustrated from the benthonic fauna. Two of the new species are described from the Arctic.

Foraminiferal distribution in the Long Island Sound—Buzzards Bay area.—L. c., No. 10, May 1952, pp. 425-473, pls. 1-5, text figs. 1-4, tables 1-6.—Three facies, one estuarine, are defined on the basis of 60 species and varieties, of which 3 are new. These are discussed and illustrated and one new name is proposed for a homonym. Distribution is represented both statistically and graphically. An estimate of temperature and salinity as controlling factors is given.

PETRI, SETEMBRINO. Ocorrências de foraminíferos fósseis no Brasil.—Univ. São Paulo, Bol. 134, Geol. No. 7, 1952, pp. 21-42, pls. 1-4, text figs. 1, 2 (maps), photographs 1-3.—Twelve species, none identified beyond genus, are described and illustrated from Miocene beds.

PHLEGER, FRED B. Foraminifera ecology off Portsmouth, New Hampshire.—Bull. Mus. Comp. Zoöl., vol. 106, No. 8, April 1952, pp. 315-390, text figs. 1-26, tables 1-18.—Notes regarding distribution are given for 58 species and varieties. Population patterns are mapped for 19 of the more important species. Distribution of 52 species and varieties is represented graphically according to sedimentary facies. Distribution is represented as percentage of the total benthonic population and is shown for over 300 stations and 18 cores. Additional tables give this information for the species found living in certain areas of fine-grained sediment (213 samples). Possible causes for redistribution of faunas as shown in core samples are discussed.

POKORNY, VLADIMIR. **Thalmannammina** n. g. (Foraminifera) from the Carpathian Flysch (in Czech with summary in English).—Sbornik Ustredniho Ustavu Geologickeho, 1951, svazek 18, pp. 469-480, 2 pls. —**Thalmannammina** (genotype **Haplophragmium subturbinatum** Grzybowski 1897) new genus of the Lituolidae.

REICHEL, MANFRED. **Fusarchaias bermudezi** n. gen., n. sp., Péneroplidé alvéolinide l'Oligo-Miocène de Cuba. —Eclogae Geol. Helvetiae, vol. 44, No. 2, 1951 (June 1952), pp. 458-464, text figs. 1-5.

ROTTGARDT, DIETRICH. Mikropaläontologisch wichtige Bestandteile recenter brackischer Sedimente an den Küsten Schleswig-Holsteins.—Meyniana, Geol. Instit. Univ. Kiel, vol. 1, 1952, pp. 169-228, text figs. 1-21.—Thirty-two species of Foraminifera, two new, are described or discussed and illustrated, and others are mentioned. Four zones are recognized.

RUSCELLI, M. A. I foraminiferi del deposito tortoniano di Marentino (Torino).—Riv. Ital. Pal. Stratig., vol. 58, No. 2, 1952, pp. 39-58, pl. 2.—Seventy-two species and varieties, of which one species is new, are recorded from the Tortonian beds of Marentino (Torino). The fauna is compared with other Italian Tortonian faunas.

SCHWEIGHAUSER, JAKOB. Ein Vorkommen von **Neoalveolina** aus dem vicentinischen Obereocaen.—Eclogae Geol. Helvetiae, vol. 44, No. 2, 1951 (June 1952), pp. 465-469, text figs. 1-5.—**Neoalveolina vonderschmitti** n. sp.

SHMAILGOWZEW, O. E. A new species of Foraminifera from Lake Balpash sediments, Kazakh (in Russian). —Acad. Nauk USSR, Doklady, vol. 75, No. 6, 1950, pp. 869-872, text figs. 1-3.—**Borovina Zernovi** n. gen., n. sp.

STEAD, FREDERICK L. Foraminifera of the Glen Rose formation (Lower Cretaceous) of central Texas.—Texas Journ. Sci., vol. 3, No. 4, Dec. 30, 1951, pp. 577-605, pls. 1-3, text figs. 1-7 (maps, tables).—A table shows the distribution and relative frequency of the 43 species, 9 of which are new, that comprise the fauna. Notes on paleoecologic interpretation are included.

STELCK, CHARLES RICHARD. Cenomanian-Albian Foraminifera of western Canada.—Stanford Univ. Bull., 8th ser., No. 67, Nov. 30, 1951, Abstracts of Dissertations Stanford Univ. 1950-1951, pp. 335, 336.—Foraminiferal assemblages are dated by calibration against ammonites. New correlations are developed. The opening up of seaway connections to the Gulf of Mexico is dated by changes in faunas.

TAKAYANAGI, YOKICHI. On some **Ehrenbergina** from Japan.—Trans. Proc. Pal. Soc. Japan, n. ser., No. 3, Sept. 1951, pp. 85-93, text figs. 1-18, 1 table.—One new species and one new subspecies are described. Seventeen species and subspecies are compared in tabular form.

Foraminifera from the Hatatate formation in the Sendai Basin.—Short Papers from the Institute of Geology and Paleontology, Tohoku Univ., Sendai, No. 4, June 17, 1952, pp. 52-64, text figs. 1-5.—The fauna is recorded and abundance plotted. Ecology and correlation are discussed and a new subspecies described.

TERMIER, GENEVIÈVE, and TERMIER, HENRI. Paléontologie Marocaine, II, Invertébrés de l'Ère Primaire, fasc. I, Foraminifères, Spongiaires et Coelentérés.—Morocco Service Géol., Notes et Mém., No. 73, 1950, 218 pp., 51 pls. (Foraminifères, pp. 29-40, pls. 1, 2).—Twenty-four species from Devonian to Pennsylvanian are described in tabular form and illustrated in section. Four species are new and two new genera are erected: **Volvotextularia** (genotype **V. polymorpha** n. sp.) and **Aoujgalia** (genotype **A. variabilis** n. sp.), the latter genus questionably placed in the Foraminifera.

TILEV, NUH. Etude des Rosalines maestrichtiennes (genre **Globotruncana**) du Sud-Est de la Turquie (Sondage de Ramandag).—Instit. Etudes Recherches Min. Turquie, ser. B, No. 16, 1951, pp. 1-101, pls. 1-3, text figs. 1-24.—Eight species (2 new and one given a new name) and one subspecies and one variety are described and illustrated in detail. Methods of preparation of material and explanation of words used are included.

TODD, RUTH. Vicksburg (Oligocene) smaller Foraminifera from Mississippi.—U. S. Geol. Survey Prof. Paper 241, June 1952, 53 pp., 6 pls., 1 distribution chart.—Descriptions and illustrations of 176 species and varieties, of which 13 species and 3 varieties are new.

TODD, RUTH, and KNIKER, HEDWIG T. An Eocene foraminiferal fauna from the Agua Fresca shale of Magallanes Province, southernmost Chile.—Spec. Publ. No. 1, Cushman Found. Foram. Res., Sept. 2, 1952, pp. 1-28, pls. 1-4, text fig. 1 (map).—The fauna includes 114 species and varieties of which 29 are described as new.

TROMP, S. W. Tentative compilation of the micropaleontology of Egypt.—Journ. Pal., vol. 26, No. 4, July 1952, pp. 661-667.—A brief resumé of a method of recognition, classification, and correlation of formations by means of quantitative analysis of genera only, with specific genera and families cited for beds of Recent to Mesozoic age in Egypt.

UCHIO, TAKAYASU. Geology of Natural Gas in the western part of Mobara-machi, Chiba Prefecture.—Journ. Japanese Assoc. Petr. Geol., vol. 17, No. 1, Jan. 1952, pp. 22-37, figs. 1-8B (in text), text-fig. 1.—**Astrononion umbilicatulum** n. sp. from lower Pleistocene.

Foraminiferal assemblage from Hachijo Island, Tokyo Prefecture, with descriptions of some new genera and species.—Japanese Journ. Geol. Geogr., vol. 22, March 31, 1952, pp. 145-159, pls. 6, 7, text figs. A-C, table 1. —The composition is analyzed and 18 species and varieties, 4 new, are discussed and illustrated. **Chrysalidinoides** n. gen. (genotype **C. pacificus** n. sp.), **Angulodiscorbis** n. gen. (genotype **A. quadrangularis** n. sp.), and **Epistomaroides** (genotype **Discorbina polystomelloides** Parker and Jones).

An interesting relation between **Stomatorbina** Dorreen, 1948, and **Mississippina** Howe, 1930, of Foraminifera. —Trans. Proc. Pal. Soc. Japan, n. ser., No. 7, Aug. 31, 1952, pp. 195-200, pl. 18.—"**Pulvinulina concentrica**" is placed in **Mississippina** and apertural differences between that genus and **Stomatorbina** are discussed.

VISSER, A. M. Monograph on the Foraminifera of the type-locality of the Maestrichtian (South-Limburg, Netherlands).—Leidse Geol. Mededelingen, vol. 16, 1951, pp. 197-360, pls. 1-16, map.—A careful work describing and illustrating 137 species, 10 new, from 5 outcrop sections. Distribution and abundance are recorded graphically.

VOORTHUYSEN, J. H. VAN. Recent (and derived Upper Cretaceous) Foraminifera of the Netherlands Wadden Sea (tidal flats).—Meded. Geol. Stichting, n. ser., No. 5, 1951, pp. 23-32, pls. 1, 2, 1 map, 1 distribution chart.—The fauna is studied quantitatively and illustrated. A new variety of **Elphidium** is described. The fine fraction (0.05-0.15 mm.) reveals many dwarf forms and the derived Cretaceous ones.

A new name for a Pleistocene Foraminifer from the Netherlands.—Journ. Pal., vol. 26, No. 4, July 1952, pp. 680, 681.

RUTH TODD

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